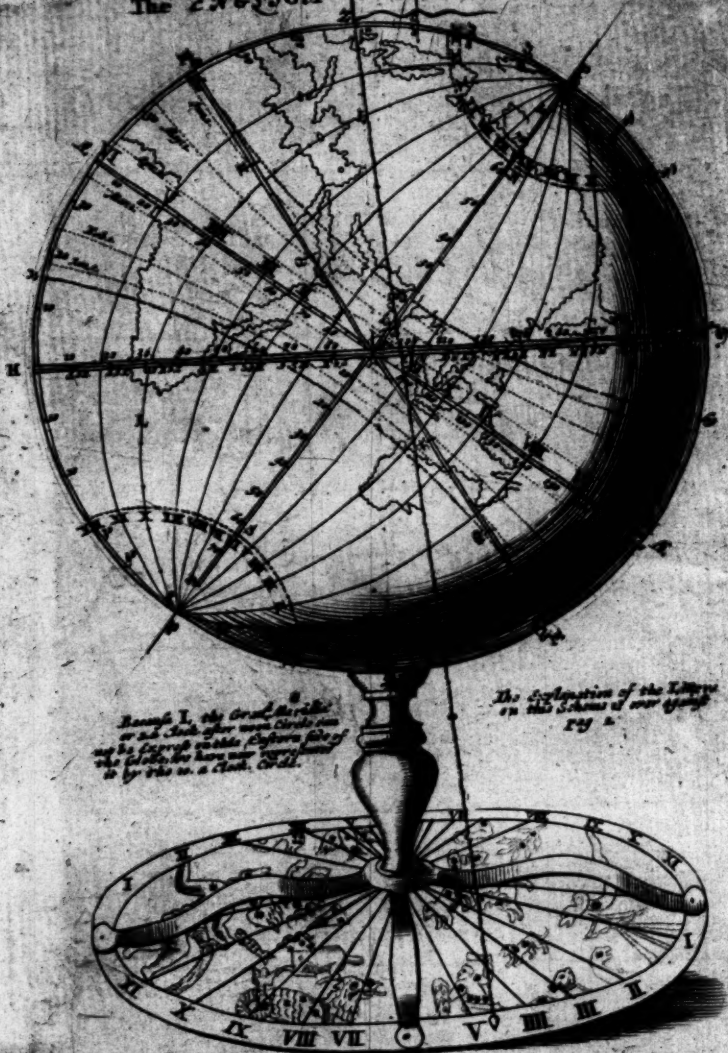


The ENGLISH GLOBE

Tab. 1.

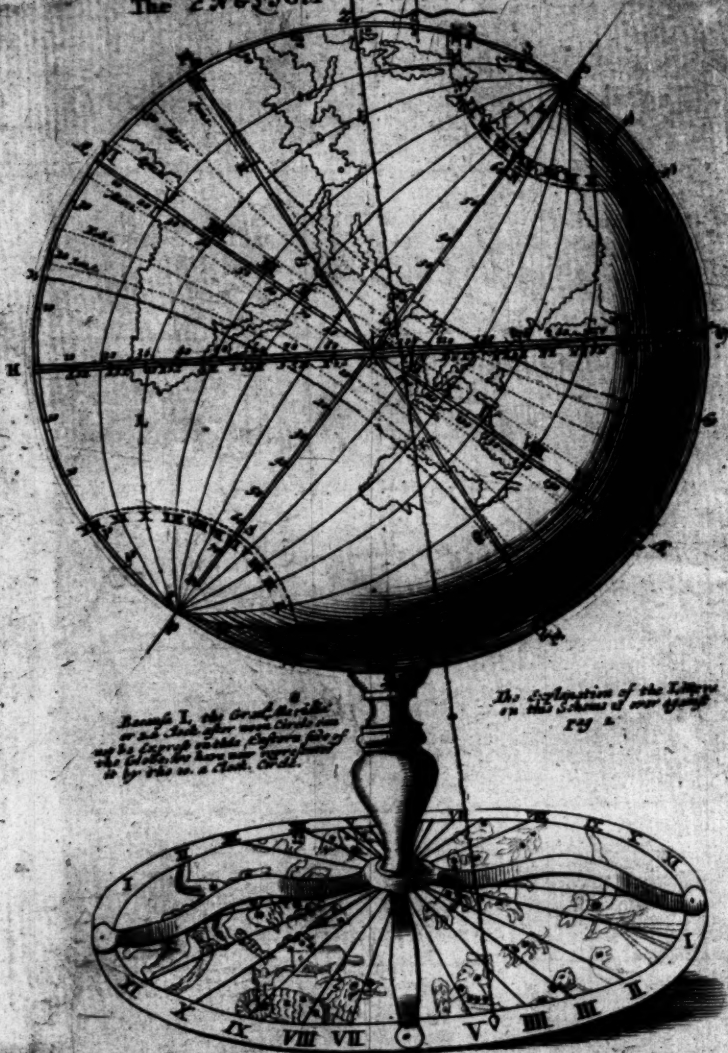


*Figure 1. the Great Meridian
or Axis, after which Circle, and
up the Earth, in the Eastern side of
the Globe, the Axis, is represented
to be the 20. a North Circle.*

*The Explanation of the Letters
on this Scheme of our globe
Fig. 1.*

The ENGLISH GLOBE

Tab. 1.



*Figure 1. the Great Meridian
or Axis, after which Circle, and
up the Earth, in the Eastern side of
the Globe, the Sun now is represented
to be the 20. a Clock, Circle.*

*The Explanation of the Letters
on this Scheme of our globe
Fig. 1.*

The English GLOBE

Being a STABIL and Immobil one
performing what the Ordinary Globes
do, and much more.



Invented and described by the Right Ho-
norable, the *Earl of Castlemaine*.

And now publish't by *Joseph Moxon*, Member of the Roy-
al Society, and Hydrographer to his most Excellent
Majesty.

Fundasti TERRAM super STABILITATE sua. Psal. 104. 5.

LONDON.

Printed for *Joseph Moxon*, at the Sign of *Atlas* on *Ludgate*
Hill. 1679.

THE CHURCH

OF THE

UNITED METHODIST CHURCH

OF THE

STATE OF NEW YORK

IN SENATE

January 1, 1882



TO THE
READER

Concerning this Globe, and the occasion of the Inventing of it.

NEW and profitable Inventions in Arts are like hidden Treasures found, which ought not to be reburied, and concealed again, but dispersed and made use of for the common good. This Globe then, and its Description (which I have humbly obtained from the Right Honorable, the Earl of Castlemaine) being both highly curious and useful, I thought I could not better serve (as I have always endeavour'd) this, and future Ages, then by communicating it to them; and because the occasion of the Invention is so accidental, and (as it proves) so happy, I shall give you a short account of it.

Waiting upon my Lord in the beginning of Anno 1672, at his then arrival into England, I brought his Lordship (knowing that any thing new and ingenious would be acceptable to him) one of my 3 Inch Terrestrial Globes, with the Stars described in the inside of its Case, which when his Lordship had considered, and bin inform'd by me, that its only Use was to keep in memory the situation of Countries, and Order of the Constellations and particular Stars, He intimated, that certainly much more might be done by it, and so returning beyond Sea fell upon this excellent Work.

When he came home again (which happned above a year ago) and was pleased to shew me what he had done, I was as much ravish'd and surpris'd at the admirable Contrivance of his Globe, and the many unexpected Operations performed by it, as if I had bin a new Beginner in the Study of the Sphere;

To the Reader.

Nor could my admiration be less, when I saw how (without the usual assistance of a Meridian Line, Mariners Compass, or other such helps) it compos'd it self to the true size and position of the World; how that in an instant, the Suns Altitude was naturally and plainly found by it, and this in all places of the World at the same time; Nor did it seem less strange to me, that so many curious Questions relating to Eclipses should be resolv'd by it, and what is more that Astronomy could possibly have any relation to a Globe. Besides, I saw that not only the Practical part of Dialling was now render'd easy to a wonder, but the Theoretical also so plain, that every mean capacity might straight comprehend it; Nay, all the forrain Requisites to this Art (as the Declination of Planes, their Inclination, Rectification, &c.) are here as artificially and exactly found, as by any Instrument invented for that intent alone.

And this I can also say, that as to the Geographical part, it is (considering its bigness) not only the most useful, but also the best order'd and the best divided Globe extant; and yet it would have bin not a little better, had not his Lordships late Troubles hinder'd him from finishing it, as he design'd for Directions are not always sufficient to express an Authors mind. But truly notwithstanding these and other prodigious Operations, that which surpris'd me with the most admiration was to find, that in a subject so trite as the Globe (and so nicely Canvass'd by the greatest Mathematicians of all Ages) any thing should be left to be added or invented to it; which also shews that the Wit of Man has no bounds; nor can any thing better demonstrate the noble Authors great Parts, who moreover (because he would omit nothing that I had offer'd at in the Proto-type) has here shew'd his excellent skill in relation to the Stars by a Projection on the Pedestal; and doubtless this kind of Projection was never brought to that perfection before.

But Gentle Reader, I shall injure you too much if I detain you longer from this rare present, and therefore after rendering again my thanks to his Honour for this favour and libertie, I subscribe my self

June 24. 1679.

His and Your Humble Servant,

Joseph Moxon.

A Postscript concerning the Erratas, and the Geographical part of this GLOBE.

THE Erratas of the Press being many, I shall not set them down in a distinct Catalogue as usually, least the sight of them should more displease, than the particulars advantage, especially since they are not so material or intricate, but that any man may (I hope) easily mend them in the very reading. I confess I have bin in a manner the occasion of them, by taking from the Noble Author a very foul Copy, when he desir'd me to stay till a fair one were written over, so that truly 'tis no wonder, if Workmen should in these cases not only sometimes leave out, but adde also, by taking one line for another, or not observing with exactness what words have bin wholly obliterated and dash'd out.

As to the Geographical part of the Globe be pleased to take notice that 1st, The Terms or Bounds betwixt EUROPE and ASIA, or between ASIA and AFRICA, are Strokes and Pricks: — — — thus: between great Empires, single Strokes in this manner — — —; and between Province and Province only Pricks. And by the way, the Author calls here an Empire, every great Tract of ground of one Appellation, as Barbary and Zara in Affric, Siam and Pegu in Asia, Italy and Germany in Europe, as well as France, Spain, Persia, &c. that belong to one only Prince. These Empires are in little Capital Letters, but the Provinces or subdivided Kingdoms are in Round Roman, as Algiers and Tunis in BARBARY, Pomeran and Austria in GERMANY, &c. and for the Towns as London, Paris, Venice, &c. they are generally in Italick, but when they happen to be in Round Roman, as Fez, Morocco, Agra, &c. it shews that the Province gives the Name to the Capital City, for the Name properly belongs to the Province, but to save trouble and room it is now by a Reference or Dash joyn'd to the Town.

2. The Old Name of any place is in Old Hand, and when

it belongs to an *Empire*, 'tis very big, as *Sarmatia*, *Ethiopia*, &c. when a *Province*, a great deal less, as *Mesopotamia*, *Caldea*, *Affrya* and the like, and when a *Town* very little, as *Sippo*, *Cyrene*, and so forth.

3. The *Hills* that are exprest have all before them the Letter *M*, and the *Capes* the Letter *C*, but the *Rivers* have eithe either an *R* or else *fl.* after them; and whereas some *Old names*, as *Thule*, *Ophir*, &c. are repeated, it is to shew where *One Author* would have their situation to be, and where *Another*.

* pag. 24.

But be pleas'd to remember, that whereas his Lordship did Direct in this *Treatise*, that the Grand *Meridian* should pass throu' *Sr. Vincent*, I have presum'd to draw it over *St. Mary* and *St. Michael*, 2 *Isles* of the *Azores*; for truly thus it suits best (according to my *Tables*) with the 2 a *Clock Circle*, as his Lordship would have it do.

An Advertisement.

BEcause there are several who either want time, or Patience to go throu' the whole *Treatise*, I here present the Reader with a *Catalogue of the Operations*, which are most pleasing and suitable to the fancy and humour of such, and which they may easily in a day or two learn, especially if they have a *Master* to help them.

1. **T**O set the *Globe level*. pag. 4.
2. To compose the *Globe*. p. 8.
3. To know the day of the *Month*. p. 9.
4. To take the *Suns height* above our *Horizon*, when he shines out clear; and also when he shines dimly, and is overclouded, p. 5. and 6.
5. To find the *Suns Azimuth* and *Bearing*. p. 10 and 12.
6. To know the *Hour* several ways. p. 13.
7. To know at what hour the *Sun* rises or sets. p. 16.
8. To know what a *Clock* 'tis all the *World* over. p. 31.
9. To find where 'tis day and where 'tis night all the *World* over. p. 33.

10. To find where (at that moment) they have nothing but Day, and where nothing but Night; as also when this happens in any place subject to this Alteration. p. 33.
11. To find the Sun's present Height and Depression all the World over, if he shines. p. 37.
12. To find where the Sun is rising and setting all the World over. p. 34.
13. To find what people have then the Sun Vertical, or over their heads. p. 35.
14. To know where they are rising, where they are going to Dinner, where to Supper, and where to Bed all the World over. p. 35.
15. To find how much any People (if it be day with them) are past Morning, or want of Evening; and (if it be Night with them) how much they are past Evening and want of morning; and consequently the Babilonish and Italian Hour all the World over. p. 36.
16. To know the Judaic Hour, p. 39.
17. To find in what Clime any Place lyes. p. 26.
18. To know in any Lunar Eclipse, what Countries see it wholly, what in part, and what not at all; as also the true hour, which each people see her at, in her several Affections; with her continual Height, Azimuth, and Bearing all the while. p. 59.
19. To represent the several Phases of the Moon. p. 61.
20. To find the Proportion between any Perpendicular and its shade. p. 65.
21. To take the height of a Tower by the Globe. p. 66.
22. To do it seemingly without any Instrument. p. 66.
23. To know the Hour by your Stick. p. 67.
24. To learn presently how to make (all the 5 Dials of a Cube, (to wit, that on its * Horizontal, that on its direct † South, * p. 73. † p. 80. that on its direct * North, that on its direct † East, and that on * p. 82. † p. 85. its direct West Plane) tho' a man be never so unacquainted with Mathematics.
25. To represent at any time the posture of the Heavens in relation to the appearing Fixt Stars; and consequently to find the present Hour, with the Height, Azimuth and Bearing of any Star; as also the time of its Rising, Setting and continuance both above and below the Horizon. p. 138.

The General Heads.

1. **T**HE Figure, or Delineation of this Globe, as also an account of it, and the occasion of its Invention together with a Catalogue of the Operations fittest for those that cannot run over the whole Treatise, are contain'd in the unfigur'd or preceeding pages.
2. The Introduction begins pag. 1.
3. The first Section, solving the Questions which relate to the Sun in our Elevation. p. 4.
4. The second Section, resolving the Operations that concern Geography, and the Sun all the World over. p. 20.
5. The third Section, concerning the Moon, p. 48.
6. The Fourth Section relating to Perpendiculars and their Shades. p. 64.
7. The Fifth Section treating of Dialling. p. 70.
- The Figure of the Globe fitted for a Garden or open Portico. p. 121.
- Geometrical Problems, necessary for Dialling. p. 122.
8. The Use of the Line of Lines, and Line of Sines on the Sector. p. 125. & 127.
9. The sixth Section, solving (both by the Globe and Pedestal) all the usual Questions which relate to the Stars, p. 129. & 135.

The Explication of the Letters, &c. on Sch. 1.

- | | |
|--|---|
| <p>P. The North Pole of the World. N. The Northern Polar Circle. Z. The Zenith. E. E. The Ecliptic. S. S. The Tropic of Cancer. Jun. 1. The Parallel of that day. May 1. The Parallel of that day. Apr. 1. The Parallel of that day. E. E. The Equator. Mar. 1. The Parallel of that day. Feb. 1. The Parallel of that day. Jan. 1. The Parallel of that day. W. W. The Tropic of Capricorn. H. H. The Horizon. S. The Southern Polar Circle.</p> | <p>P. The South Pole. N. The Nadir. Z. H. The Quadrant of Altitude; P. The Quadrant of Depression. Z. P. The Quadrant of Proportion. P. E. P. The Meridian of the Place or Solstitial Colure. LL. The Meridian of the World. Y. P. P. The Equinoctial Colure. XII. I. II. &c. The Hour Circles, or particular Meridians.</p> |
|--|---|

THE Introduction.

THIS *Globe* whose several *Operations* we are here describing, neither hangs in a *Frame*, nor is moved about as the ordinary ones are, but stands *stable* and *immobil* on its *Pedestal*, which makes it not only to represent the *Earth* more naturally, according to the common *Hypothesis*, but renders it also more expedite and useful, as shall be fully shewn in the *Conclusion* or last *Chapter*; for then (after a view of the whole *Treatise*) every body will the better comprehend all the new *Operations* it performs, and all the particular *Advantages*, it can any ways challenge to its self. But here my *Reader* must remember that though I endeavour all along (even in the most ordinary things) to be clear and easy, yet unless he has formerly read, *Hewes*, *Blean*, or rather *Moxons* Book on the *Globes*, I cannot promise him I shall always be understood without the help of a *Master*; for I have not time to descend to all the *Definitions* and minute *Explanations*, which those that are wholly unacquainted with *Astronomical* or *Geographical* Principles, may perchance expect.

As for the *Circles* here describ'd, there are some common *Of the Circles* to all *Globes*; as the *Equator*, the *Ecliptick*, the *Coluri*, the describ'd on ordinary *Circles of Longitude*, the *Tropics*, and the *Polar Circle* the *Globe*. and some also particular to this *Globe* only, as the *Horizon*, the *Meridian* of the *Place*, and 16 *Parallels* to the *Equator*, all within the said *Tropics*. Now that these *Circles* in general may be the sooner found and comprehended by any new *Beginner*, there are *Capital Letters* in the *Great Figure*, or *Delineation* of the *Globe*, in *Scheme* the first, which sufficiently distinguish

distinguish them; for the *Equator* is markt with *A*, the *Ecliptic* with *E*, the *Polar Circles* with *N*. and *S*. The *Circles of Longitude* with the *Roman Figures*, I. II. III. &c. as well where they fall upon the *Polar Circles*, as the *Equator*; and tho all the *Circles*, that thus cut the *Equator* and *Polar Circles* at a *Roman Figure* be *Circles of Longitude*, yet they now serve for true *Hour Circles* also, since they are not here express'd, and drawn (according to the usual manner of *Terrestrial Globes*) at the distance of 10 *Degrees*, but of 15 asunder. And here be pleas'd to remember that since there is a difference between the *Roman Figures* which belong to the same *Circle* (for if it cuts for example at IIII. on the *Polar Circles*, 'twil cut, you see at six hours difference, viz at X in the *Equator*,) the reason of it will appear by and by very plainly when we come to the *Operations*, that concern these *Circles*; of which the broadest (passing through the *Zenith* and *Nadir*) has two *Quadrants* gradually divided on one half of it, the first called the *Quadrant of Altitude*, reaching from the *Pin Z* or *Zenith*, to the *Horizon H*, the second (called the *Quadrant of Depression*) reaching from thence to the *Nadir*; whereas on the other half, or back part of the said *Circle*, there is a single *Quadrant* only, viz. from the *Zenith* to the *Horizon*, which we shall for the future term the *Quadrant of Proportion*. This *Circle* is also markt on the *Polar Circles* with the *Figure XII*. representing thereby, not only the 12 a *Clock hour Circle* or *Meridian* of the place, for which the *Globe* is particularly design'd, but the *Column Solstitiorum* also; so that the *Column Equinoctiorum* must be the 6 a *Clock Circle*, whose half is (as you see) divided for several uses into *Degrees* from *Pole* to *Pole*. By these two *Circles* then, you have readily presented to you the 4 *Cardinal Sections*, or *Points* of the *Globe*; for as the *Graduated* half of the said *Meridian*, shews the *Globes Southern* part or face, and the opposite its *Northern*, so the graduated half of the six a *Clock Circle* gives its *Eastern*, and the plain side of it its *Western*. Now for the *Equinoctial Parallels*, or *Sun's Track* for every 10th day, throughout the year, (for to avoid Confusion of *Circles*, I describe no more) they are distinguish'd by the *Days* of the *Month*, when the *Sun* comes to them, the uttermost of which are the two *Tropics* markt not only with the 11th. of *June* and 11th. of *December*, but with 6 and 17, the usual Characters

The 4 Cardinal points of the Globe.

acters of *Cancer* and *Capricorn*. Lastly, for the *Meridian of the World*, or first *Circle of Longitude*, 'tis markt with the Letter *L*, and prickt also; and tho in the present *Longitude* (i. e. that of *London*) it stands for the 2 a Clock *Hour-Circle*, yet in its self 'tis changeable, as shall be shewn hereafter, when we treat of its * Properties, and Divisions.

* vid. Oper.
2. & 5. in
Sect. 2.

These are then the *Circles* here describ'd, either common, (as I said) to all *Globes*, or particular to this, and being well observed and remembred will much facilitate the ensuing *Operations*, which are all naturally performed, either by the shadow of the *Sun* and *Moon* alone, or by the help of a small *String*, hanging sometimes from the *Pin P*, representing the *North-Pole*, sometimes from the *Pin Z*, representing (as I said) the *Zenith*, and garnisht with a little *Bead* and *Plumet*, according to its *Figure* in the *Scheme* afore said.

What the
Operations of
the *Globe* are
perform'd
with.

And here you are to take notice that tho the one end of the *String* be absolutely fastned to the *Pole*, to prevent the loosning of it, yet 'twill serve for the *Zenith* as commodiously as if it always hung from thence; for there is made at a convenient distance from the said fastned end, a little *Noose* or *Ring*, which (as occasion requires) is now to be over this *Pin*, and now over that; Nay if you give your *String* but half a turn about either of the *Pins*, you will (with a little Allowance) as exactly perform your *Operation* as if you used the said *Noose* it self.

A Memorandum.

To conclude, the whole *Treatise* is divided into six *Sections*; The first solving several *Questions* that relate to the *Sun* in our *Elevation*. The second, many *Geographical* ones, together with some that concern the *Sun*, not only where we live, but all the *World* over. The third is of the *Moon*; The 4th. of the *Proportion of Perpendiculars to their Shades*, with some useful *Corollaries* thence arising; The 5th. of *Dialling*, and the 6th. of the *Stars*.

How the
Treatise is
divided.

SECT. I.

Solving many questions, relating to
the Sun in our Elevation.

Operation I.

To set the Globe level or parallel to the
Horizon.

The first way. **I** Begin here, because 'tis what we first suppose done in most *Operations*, especially in the nice ones, nor is the performance difficult, for we have nothing to do, but to place the *String* and *Plummet* exactly upon the South side of the *Meridian* or 12 a *Clock hour Circle*, and if it hangs just over the little *Star* on the *Pedestal*, then the *Plane* where the *Globe* stands is *Horizontal* and *Level*, otherwise 'tis faulty as much as the *Plummet* varies from being *Perpendicular* to the said *Star*, for the *Star* (you must suppose) is engraved by the *Globe-maker* there, where he found the *Plummet* to hang upon his Placing the *Globe* truly level.

A Memorandum.

Let therefore the *String* and *Plummet* be always long enough to touch almost the *Pedestal*, for thereby you may better perceive any *Error*, and remember also that in case the said *Pedestal* (to be less cumbersome) be not as big as the *Diameter* of the *Globe*, then there is to be under it a little wooden *Ruler*, which being drawn out, and markt with a *Star* will serve for this and several other uses as you will see anon.

The second way.

There is another way speculatively true, tho perchance not so exact in practice, which is thus perform'd. Place your *Globe* on your *Plane* with the *String* lying on the *Meridian* as before, and if the *Extuberancy* or swelling of the *Globe* just touches and bears up the *String* at the *Horizontal Circle*, then
the

the *Plane* is *Level*, or *Parallel* to the *Horizon*, otherwise it differs as many degrees, as are between the point, where the said *String* touches the *Globe*, and its *Horizon*.

The reason of this is, That seeing the greatest and most extuberant *Circle* on a *Globe* is that which lies 90 degrees from its *Pole*, the *Horizon* becomes here the greatest and most extuberant one that can be described from the *Zenith*, therefore the *Globe* being on a *Level* which makes its *Zenith* to correspond with the *Zenith* in the *Heavens*, the *String* cannot fall short of the *Horizon*, because it must rest on the most extuberant *Circle* that occurs; nor can it touch below it, because the *Plummet* drawing the said *String* perpendicular from the greatest extuberancy, hinders its bending, and consequently its inclination to any part of the *Globe* beneath the *Horizon*. Now if the *Plane* be not *level*, then the *Zenith* of the *Globe* and *Heavens* not corresponding, another *Circle* or part of the *Globe*, instead of the *Horizon* must have the greatest extuberancy and this *Circle*, being 90 Degrees from the point of the *Globe*, (which lies directly under our *Zenith*) it must differ from the *Horizon* of the *Globe*, as many Degrees as its *Zenith* differs from that in the *Heavens*; therefore the way prescribed is at least speculatively true.

The Reason and Demonstration of the Operation.

Operation II.

To find the *Suns Almucantar*, or Height.

There are three distinct ways of performing this independent of the following *Operations*; and each of great use; for the first gives you the *Suns* height in an instant if he shines. The second if you have the least glimpse of him, or can guess at his place in a *Cloud*. The third, if you know the hour by any good *Watch*, *Pendulum* or the like, whether we see the *Heavens* or no.

1. As for the first way, 'tis this, your *Globe* being level, move it 'till the shade of the *Pin* in the *Zenith* falls directly upon

The first way.

the *Meridian*, and then the *shade of the Extuberancy* (i. e. that made by the swelling or belying out of the *Globe*) will touch the true degree in the *Quadrant of Altitude* reckoning from the *Zenith* to it. And thus you will find not only the *Sun's* height, sooner perchance than by any ordinary *Quadrant*, but will still have it before your eyes as long as you please, nothing being to be further done, but to move sometimes the *Globe* that the shade of the said *Pin* may still concur with the *Meridian*. But if your *Globe* be fix'd, (or that for some particular reason, you have no mind to stir it at all, draw your *String* from the *Zenith*, through the shade of its *Pin*, i. e. lay the *String* in the Plane of the *Sun*, and then if you mount your *Bead* till it reaches the nearest part of the *shade of Extuberancy*, it will (by bringing it to the *Meridian* or *Quadrant of Altitude*) lye on the true *Degree*, reckoning (as before) from the *Zenith* to it.

The Reason
and Demon-
stration of
the operation.

The Reason of the Operation is this; The *Sun* when he rises brushes the *Zenith* and *Nadir* of the *Globe* with his *Rayes*, for he illuminates alwayes (within some few Minutes) just half of it, therefore when he gets (v. g.) a Degree higher, he must needs illuminate a Degree beyond the *Zenith*, and so proportionably from time to time, or else he would sensibly illuminate more or less of the *Globe* at one moment than at another, which is absurd. Now since the *Sun* in truth illuminates more than an Hemisphere, the Reader must remember that *Ptolomy* reckons this excess (take one time with another) to be about 26 minutes, and *Tycho* something less, therefore subtract 13 minutes (or half the said Excess) from what the *shade of Extuberancy* mark's, and you have his *Height* with all ordinary Exactness: but should you chance at any time to doubt how far the said *Shade of Extuberancy* (which is not so discernable as that made by a *Gnomon*) just reaches, erect then a piece of stick, straw, quill, &c. or, if you please, rest your Finger on the *Globe*, between the *Sun* and the point in dispute, and where the shade of your Finger, straw, stick or quill is lost, that will be the true Term of the shade.

How much
the *Sun* illu-
minates more
than half the
Earth.

How to know
the term of
the shade of
Extuberancy
when the su-
bines faintly.

The second
Way.

As for the Second Way (for both the former we reckon but one) turn the *Meridian* of your *Globe* to the *Sun* as before, or because we suppose him not to shine out-right, direct by your Eye the said *Meridian*, so that it lye in the same Plain with him, and this you may do in a manner as well (if you have the least

least glimpse of him, or can by any accident guess whereabouts he is) as if you had the fore-mentioned help of the *Pin's* shade in the *Zenith*. Having thus done, Take your *String* in both hands, and cross with it (as exactly as you can at right Angles) that part of the *Meridian* next your body, whether it happens to be the *Quad. of Alt.* or that of *Proportion*, then putting your Face close to it, and moving your Ey lower and lower, till by reason of the Extuberancy you can but just see the *Sun*, or his supposed place in Heaven, do but bring your *String* (held as before) to this point, viz. bring your *String* towards you till it just takes away the *Sun* or his supposed place from your Ey, and the degree in the *Meridian* on which it then lies will be (counting from the *Zenith*) the *Height* required; for so far his raies would reach did he shine out-right.

The third way is when we know the Hour by any Watch, Pendulum, The Third &c. thus, Find among the *Aequin.* or *Diurnal* *Parallels* that belonging way. to the present Day, which we will suppose *Apr. 10.* and drawing your *String* from the *Zenith* over that Point in the said *Parallel*, where² is cut by the Hour given, i.e. by the morning 9 a *Clock Circle*, move your *Bead* to the said Point, and the distance from the *Bead* to the *Horizon* will be the required *Height*, viz. about 36 degrees, as you'll find if you bring the *Bead* to the *Meridian* and count the degrees between it and the *Horizon*.

The *Sun's* Height may be also known by its *Azimuth*, as by *Operat. 5.* To know at Having therefore by any of the aforesaid waies his Height, it will (upon any time any doubt) soon appear whether it be *Fore* or *Afternoon*, for as long as ^{whether it} ever he increases in Degrees, i.e. mounts higher and higher above the *Ho-* ^{be Forenoon} *rizon*, it wans of Noon, whereas if he falls or declines, 'tis after Noon. ^{or After-} noon.

OPERAT. III. To Compose the Globe, either by a *Meridian Line*, or without it, to the use of the World.

IF you have a *Merid. line* drawn, viz. a *Line* lying exactly North and South, place the Globe* level with its *Merid.* directly over it, i.e. * *Operat. 1.* place so the little *Notch* in the *Pedestal* (markt S) that it cover the *South-* ^{Page 4.} *ern* extremity of the said line, and the *Notch* N the *Northern*, and then the *Poles* and *Circles* on the Globe will (without sensible error) correspond with those in Heaven, and each painted Region or Countrey on it, will be turn'd towards the real one which it represents.

But if you have no line drawn, Know the day of the Moneth, and you have two quick waies to do this *Operation* without any foreign helps.

The *Globe* having in it smal pin-holes, on the several intersections of A way to compose the *Merid.* with the aforesaid *Diurnal* *Parallels*, or (to be exacter) on each point of the *Merid.* which an imaginary *Parallel* of each fifth day ^{Globe by} *would cut*, for tho' we are to suppose *Parallels* for every day throughout the ^{the Sun.}

the year, yet there being no sensible difference in the *Sun* from 5 daies to 5 days, such holes will be abundantly sufficient; nay the aforesaid ones from ten Dayes to ten Days, may very well serve the turn in any ordinary Operation: I say, the *Globe* having holes in its *Meridian* at this distance, put the *Zenith Pin*, or, if you think better a *Needle*, in the Hole, which most agrees with the true day of the Month, and then exposing your *Globe* level to the *Sun*, do but move it till the shade of the said *Needle* or *Pin* falls directly along the *Diurnal Parallel* where 'tis placed; or, if it be not placed in any of the said *Parallels*, move the *Globe* till the shade falls parallel to the next *Diurnal Parallel*, and 'twill be as truly *Compos'd* as before, supposing you know (as we have already

* Operat. 2.
pag. 7.

* taught you) whether it be *Forenoon* or *Afternoon* when you operate; for, as in the Morning the *Stiles* of *Dials* cast their shades *Westward*, and in the Afternoon *Eastward*, so must your *Needle* or *Pin* do when the *Globe* is *Compos'd*.

A Memo-
randum.

But here the Reader must take notice, that in case the shade of the *Needle* or *Pin* will by no means fall sensibly parallel, but (as you move the *Globe*) draws nearer and nearer its being so, till at last it shortens to nothing, then the *Sun* is exactly *South*, and consequently your *Globe* is compos'd, as soon as the shade thus vanishes.

Now, Because the shadow of the *Pin* is on the *Globe* an Arch of a Great Circle, this way of *Composing the Globe* cannot be accounted *Mathematically* true, For as the *Sun* approaches each *Tropick* and the *Tropicks* not Great Circles, it will happen Mornings and Evenings (when the *Pin* projects long shadows) that the shadow of the *Pin* will not ly exactly in the Parallel of the Day, but will (more or less) intersect it in the Center or *Pin-hole*. Therefore tho' the aforesaid way of *Composing the Globe* be true enough for ordinary uses, yet I shall give you two other waies without exception.

The first
way of Com-
posing the
Globe.

Observe the *Concentrics* between the *North Pole* and its *Polar Circle*, and first you will find that they are equal in number to the *Parallels*, either from the *Equator* to the *Tropick of Cancer*, or to those from the said *Equator* to *Capricorn*; for to avoid the confusion of too many *Parallels*, there are usually but 8 *Northern* and 8 *Southern* described on the *Globe*. 2ly. That they are distant from the *Pole* as the said *Parallels* are from the *Equator*. And 3ly. That they are markt not only with the *Daies* of the Month of the *Northern Parallels*, but with those of the *Southern* also. The Day of the Month then being (for example sake) *Apr. 10.* Move but the *Globe* (when level) till the shade of *Extuberancy* touches the *Concentric* markt *Apr. 10.* and 'twill be truly *Compos'd*; supposing that the *Eastern* face of the *Globe* looks towards the *Forenoon* or *Eastern* parts

of

of Heaven, and the *Western* face towards the *Afternoon*. In like manner, If the *Day of the Month* or *Suns Parallel* be an imaginary one between any two that are express'd, for to avoid (as I mention'd) the confusion of too many *Parallels* there are usually but 8 *Northern* and 8 *Southern* described; I say in like manner, If the *Day of the Month*, or *Suns Parallel* happens thus, let the said *Shade* but touch or fall proportionably between the correspondent *Concentrics*, and the *Globe* will be *Compos'd*, as before. *The Demon-*

The reason of the *Operation* is this; The *Sun* illuminating (as has been said) half the *Globe*, the *Shade of Extuberancy* (or in other terms the *Con-*
fines between the *Obscure* and *Illuminated* parts) will be still 90 degrees from the point or place where the *Sun* is vertical; therefore if the *Sun* be (v.g.) in the *Equator*, the aforesaid *Shade* or *Illumination* must terminate in the *Poles of the World*; and when he is in the *Parallel of Ap. 10.* the *Illumination* must fall short of the *South Pole*, and go beyond the *North Pole* as many degrees as the said *Parallel* declines from the *Equator*; But the *Concentric of Ap. 10.* is by *Construction* just distant from the *Pole* those degrees; Ergo when the said *shade of Extuberancy* or the *Illumination* touches this *Concentric*, the *Globe* must (if its *Eastern* face looks towards the *Fore-noon* part of Heaven or the *Western* the *Afternoon*) be illuminated as the *Earth* is, and consequently *Compos'd*, for its corresponding with the *Earth* in its *site* and *position* is all we mean by *Composing*.

As for the reason why I mark each *Concentric* with the 4 opposite *Months*, whereas the *Parallels* are mark'd only with 2 of them, 'tis that the *Globe* may be *Compos'd* by the help of the *Northern Concentrics*, even when the *Sun* is in his *Southern Declension*, it being more convenient and ready for one to cast his *Ey* on the *North Pole* than to stoop to the *South Pole*, about which otherwise there must have been the like number of *Concentrics*, and mark'd as the *Southern Parallels* are; I say this is the reason of thus marking the *Concentrics*, for since the *Sun* in its *Northern declension* illuminates beyond this *Pole*, he must in his *Southern* fall proportionably short of it; therefore move the *Globe* as before (let it be *Summer* or *Winter* or any other time of the *Year*) till the said *Illumination* or *Shade* touch the *Concentric* mark'd with the *day of the Month*, and 't will be still *Compos'd*.

The second way I shall defer to *Operat. 10.* because the intermediate ones conduce much to the facilitating it, as you'll see. *The 2d way vid. Op. 10.*

OPERATION IV. To find the Day of the Month.

This *Operation* is also perform'd two ways, as being the *Converse* of *The 1. way.* the former; therefore since that requires the knowledge of the *Day of the Month*, this must require the *Globe Compos'd*. Having then

Compos'd it by a *Meridian* line, or otherwise, Consider upon what *Ex-centric*, or between which of them the said *Shade of Extuberancy* or *Il-lumination* falls, and that will shew the Day of the Month.

The Second
way,
vid. C. p. 10.

As for the second way, you shall have it when we come to *Operat. X.* which treats (as we said) of the *Second way of Composing the Globe.*

OPERATION V.

To find the Sun's Azimuth.

THE *Sun's Azimuth* is an Arch of a great Circle, which passeth through the *Zenith* and *Nadir* over his body, so that his *Mornings* or *Afternoons* distance (reckon'd by the Degrees of the *Horizon*) from the *Meridian* or *Southern Cardinal* section of the *Globe* is the thing requir'd; and for performing the *Operation* there are four several ways.

The first
way.

* *Operat. 3.*
pag. 8.

* *Compose* your *Globe*; Then standing on the illuminated side, or side next the *Sun*, and fixing your *String* by its nooze in the *Zenith*, hold it up by the *Plummet-end*, and move it along till its *Shade* falls on the middle of the *Fulcrum* or supporting *Pillar*, or (to be more exact) till it covers the *Center* of the *Projection*, being the point (you see) directly answering the *Nadir*; for then the *Degree* in the *Horizon*, which the said *Shade* falls upon, gives from the above mentioned *Meridian* the requir'd *Azimuth*. Or else guide your *String* by winking (or by any other convenient means, which practice will show you) till it concurs with the *Shade* of the *Zenith-pin*, that is to say, till they both ly in the same *Plane*; for then the *Shade* of the *String* it self (if it hangs strait along the *Globe*) will cut the *Horizon*, as before.

The second
way.

In case you have onely a glimpse, or faint sight of the *Sun*, then stand (the *Globe* being Compos'd) on the obumbrated, or other side of it, and letting your *String* hang down on that side also, aim or look along it with one *Eye* towards the *Sun*, and role the *String* gently with your finger backwards or forwards, till it lies exactly in the same *Plane* as the *Sun* does, or (if the *Clouds* suffer you not clearly to see him) till it lies in the *Plane* of its supposed *Place*, and the *Degree* under your *String* (reckoning the contrary way, that is to say, from the *Northern* or back part of the *Meridian*) is the requir'd *Azimuth*. Therefore (by the by) if the *Sun* shines out, 'tis but drawing the *String* through the *Shade* of the *Zenith-pin*, and it will (reckoning thus) answer the *Question*.

The Third
way.

vid. *Oper. 2.*
pag. 5.

3dly, Having taken the *Sun's* **Height*, and having found it to be, suppose 36 deg. bring the *String* to the *Merid.* and by the help of the *Deg.* in the *Quad. of Alt.* Mount the *Bead* above the *Horizon* 36 deg. which *Operation* we shall frequently call hereafter, *Rectifying your Bead* in

The Description and Use of the English Globe.

II

the Sun's height. I say having taken the Sun's height, and Rectifi'd your Bead to it, put your Ring or Noose on the Zenith, and move your String, till your Bead lies exactly on the Parallel of the Day. Which we will alwayes in our Examples, or for the most part at least, suppose to be that of the 10th of April, and the said String will cut the Horizon at 58 Degrees Eastward (or thereabouts) for his then true Azimuth. And here you may remember, That as the Height gives the Azimuth, so the Azimuth once known, gives the Height; for your string being on the true Azimuth, if you mount your Bead to the Parallel of the Day, it will show you in the Meridian the requir'd Height.

A Memorandum.

Fourthly, Supposing that on the 10th of April, the hour given be 9 in the Morning, draw your String from the Zenith over the Point where the Parallel of the Day, and the 9 a Clock hour-Circle intersect, and it will fall on the 58 Degree in the Horizon Eastwardly of the Meridian for the then Azimuth. The 4th way.

OPERATION VI.

To find the Sun's Declension, Parallel, and Place on the Globe at all times.

BY the Sun's Declension is meant, his Northerly and South-erly distance from the Equator, therefore if you know the day of the Moneth to be the 10th of April, you have his Parallel, because 'tis mark'd with the said day: Now since the Columnus Equinoctiorum, or 6 a clock Hour Circle, is (as we said) gradually divided from the Equator to the Poles; and that the said Parallel passes almost throu' its 12th Degree, you have his Declension, as also his Place in his Parallel, if you have his Almucantar, or Azimuth as you will find by the second or following way. The first way.

If now you know not the day of the Moneth, Take the Sun's Almucantar and † Azimuth by some of the foregoing ways, and Rectifying your Bead to the Height, draw your String from the Zenith on the Horizon, according to the Azimuth found, The 2. way.

* Op. 2. pag. 6.
† Op. 5. pag. 10

A Memorandum.

found, and your *Bead* will lie on his true *Place*, and consequently show his *Declension* and *Parallel*; for, as his *Declension* is (as we said) his Distance from the *Equator*, so his *Parallel* is a Circle described from the *Pole* according to his *Declination*. And pray observe well this second *Way*; for tho' it be not extremely necessary in Relation to the *Sun*, yet it is of singular use, when you come to the *Moon* and *Stars*, whose *Declensions* depend not on the day of the Moneth.

OPERATION VII.

To find the Sun's Bearing, i. e. in what part of the Heavens he lies, according to the Points of the Compass.

HAVING found by the foregoing Operation (on the 10th of April) the Sun's true Place in his *Parallel* to be, suppose there where the 9 a Clock Hour Circle cuts it, lay over this Point your String, from the Zenith, and 'twill fall at the Horizon a little beyond the Character of S E b E for his Bearing according to the Points of the Compass.

OPERATION VIII.

To find when the Sun comes to true East or West, or any other Bearing.

HAVING found the *Parallel* of the Day (viz. that of the 10th of April) and put your String over the Zenith, bring it straight to the East point, that is to say, to the point of the Globe where the Horizon and 6 a clock Circle intersect, and you will find the said String to cut the said *Parallel* about 20 minutes before 7 in the Morning, which is the exact time of the Sun's then coming to full East. Now if the String be laid on the Western Intersection, 'twill cut the said *Parallel* at 20 minutes or thereabouts after 5 in the Evening, for the time of the Sun's

com-

coming to full *West*. In like manner, if you would know, when he comes (*v.g.*) to *S.W.* you are only to draw your *String* (as before) over that *Bearing*, and you will find by the Intersection of your said *String* and *Parallel*, that at a *quarter past 2* of the *Clock* in the *Afternoon*, or thereabouts he will have that *Bearing*.

OPERATION IX.

To find what Signs and Degrees of it the Sun is in, at any time.

SEEK out the *Parallel of the Day* (*viz.* that of the 10th of *April*) and you will find it to cross the *Ecliptic* in two places, to wit at the first of *Taurus*, and the first of *Leo*; Now because in *April* the *Sun* is still *Ascending*, that is to say, the *Dayes* encrease, you may conclude that the first of *Taurus* is his then true place in the *Ecliptick*; for were he in *Leo* he would descend toward the *Aequator*, and consequently shorten the *Dayes*.

OPERATION X.

To find the hour of the Day by the Sun, together with a second way of composing the Globe, and finding the Globe, and finding the Day of the Month.

MANY are the wayes to perform this Operation as to the *Hour*, But now wee'l insist on four only, each of which has some peculiar Propriety belonging to it; for the First gives us the *Hour* by the help of the *Natural Stile*; the Second by an *Artificial one*; the Third without any *Stile* at all; and the Fourth (together with the said hour) the Contemplation of several pleasing Operations at a time, and among the rest this of *Composing the Globe by the Shade*.

1. Having **Compos'd your Globe*, (and thus wee'l suppose it *The 1st. way.* in each of the following wayes) look among the *Hour Circles* **Op. 3. pag. 8.* (which are, as we said, distinguish'd near the *Polar Circles*, with

little *Roman Figures*) and the shade of the *North-Pole*, or *Axis* of the *World* (which we may justly call the *Natural Stile*) will, during the *Sun's* Northern Latitude, as well as the shade of the *South Pole* in his Southern, shew you the *Hour*. And thus you may find it for a while by the Ordinary Globes, in *Circulo Horario*, when they are once set or *Compos'd*, which I wonder none, of those who writ of their *Uses* take notice of; I say for a while, for it will only serve you ~~from March to September.~~

The 2. way.

II. Your *String* hanging by one End on the *North-Pole*, hold it straight by the other, some little distance from the *Globe*, and moving it on the *Noose*, till its shade touch, or cover, the *Apex* of the *South-Pole*, 'twill show you (among the afore said *Polar Roman Figures*) the true *Hour*, even to a minute; for the *Shadow* of the *String* (which we call an *Artificial Stile*, because 'tis Independent and Forrein to the *Globe*) cutting at that Instant the *Aequator*, and *Polar Circles*, gives you in each place the *Degrees* of the hours, and consequently the minutes, since the 4th part of a *Degree* is an exact minute in time.

The 3d. way.

III. Look where the shade of *Exuberancy* cut's on the *Aequator*, and the great *Roman Figures*, (which are there for that purpose) will give you without a *Stile* or more adoe the exact hour, on what side soever of the *Globe*, you stand; for you must remember that the *Exuberancy* casts on the *Aequator* two shades, the one still *Preceding* or going before the *Sun*, and the other *Following* him. Now if this shade be dubious, your Finger (as I shew'd you * before) will help you, it being the constant Remedy on all Occasions of this Nature.

* 2. pag. 6.

The 4th. way.

IV. As now you find the *Hour* by your *String* hanging on the *Pole*, so this Fourth way is to show it you, in case it had hung on the *Zenith*; nor have you more to do than to hold it by the end as before, and to move it on its *Noose* 'till its shade concurs and agrees with that of the *Pin* in the *Zenith*, or for more Assurance till the *Strings* shade fall's so on the upper part of the *Pillar* or *Fulcrum* that it would cover the very *Nadir*, were it not hid, and then where the said *String* it self, or its shade cuts the *Parallel of the Day*, there will be the true hour, according to the *Roman Figures* of the *Polar Circles*.

con-

This way I would have you well observe for from hence I shall hereafter lead you to the Contemplation (as I hinted before) of several pleasing and useful * Operations at one glance or view; and to give you a little Taste at present, I will here shew you the Second way of *Composing the Globe* by the shade.

Having for Expedition's sake, turned the *North-pole* of the *Globe*, as near as you can guess to that of the World, Hold up your *String* with one hand to the *Sun* in the manner now prescribed; That is to say, 'till the *String* hanging from the *Zenith* casts its shade on the *Nadir*, then move the *Globe* with your other hand, and making by a proportionable motion of the *String* its shade to pass still throu' the said two points, observe when it cuts the *Parallel* of the day at the like hour with that, which the shade of the illuminated *Pole* indicates, and your *Globe* will be composed; or, to express this in fewer words, Move thus the *Globe*, till the shade of the *string* and the shade of the illuminated *Pole* agree in the Hour. Nay fixing your *String* in the *Zenith* as before, and fastning a *Thread* on the *North-pole*, do but hold up both to the *Sun* till the shade of the *String* passes the *Nadir*, and that of the *Thread* the *South-Pole*, if any body then moves your *Globe* about till the two shades (passing still throu' the forefaid Points) intersect on the *Parallel of the Day*, you have your intent; for the *Sun* being you see in the Planes of the *Thread* and *String* he must be in their Intersection. i.e. in the *Parallel of the Day*; but 'tis impossible for him (as we * shew'd you) to be in the plane of that *Parallel*, on the true side of the *Meridian*, except the *Globe* be Compos'd, for the corresponding *Circles* of the *Globe* and *Heavens* can never else agree; therefore the *Operation* is true; and if so, let the *Globe* be but on a *Meridian Line*, or any way else Compos'd, and the Agreement of the hour in both places, or the Intersection of these two shades shews the *Sun's Parallel* and consequently the *Day of the month*.

So much then for this second way of composing the *Globe*, and finding the *Day of the Month*, which first came into my thoughts by reflecting on the *Projection* of that great man Mr. *Onghed*, who would have bin the Wonder of this Age, had he bin as ambitious and forward, as he was thoroughly learned.

A Memorandum. * vid. the particulars in the conclusion or last Chapter.

The 2d. way of composing the *Globe* by the shade.

Demonstration.

* Op. 3. pag. 8

The 3d. way of finding the day of the month.

OPERATION XI.

To find the Hour of the Day when the Sun shines not.

*Op. 2. pag. 6
 & Op. 5. pag.
 10.

TO perform this Operation, we must suppose you know either the Sun's *Almucantar*, *Azimuth* or *Bearing*; and by the way you may find these, tho he * shine's not; I say you must suppose either his *Almucantar*, *Azimuth*, or *Bearing*, for they giving you his *Place* in his *Parallel*, the next *Hour Circle* to his said place shews you the time of the Day; for if (v.g.) in the forenoon on the 10th of *April*.) you know that the Sun is 36 degrees high, *Rectify* your *Bead* but to that height, and moving the *String* from the *Zenith* your said *Bead* will touch the *Parallel of the Day* at 9 of the *Clock*. In like manner if you know the morning *Azimuth* to be suppose, 58 degrees, draw your *String* from the *Zenith* over the said Degrees in the *Horizon*, and 'twill also cut the *Parallel of the day* at 9. Or, if the Sun's *Bearing* be (for Example) a little more than S E b E the laying of your *String* from the *Zenith* on that Character in the *Horizon* shows you on the *Parallel of the day* that 'tis 9 as before.

OPERATION XII.

To know when the Sun rises and sets.

FIND the *Parallel of the Day* (to wit that of the 10th of *April*) and where it cuts the *Horizon* on the *East* side of the *Globe*, there the Sun's place at his *Rising* will be so that the time of the day appears by the next *Hour Circle* to be a very little past 5 in the morning; and if you cast your eye in the *Interfection* of the said *Circle* on the *West*, you'll find the hour to be almost 7 in the *Evening*.

To find when,
 and at what
 declension, the
 Sun rises or
 sets earlier or
 later, accord-

This being so, here follow's a very pleasant and useful Operation, as a Corollary, viz. How to find at what time of the year, and at what Declension the Sun rises or sets, an Hour, or any other space of time, either early or later, than it does at the proposing of the Question: for, if you observe but what *Parallel* in-

tersects

sects with the *Horizon*, on the 4 a Clock morning hour-circle which is an hour earlier than when it rises on the 10. of *April*, you will find it an *Imaginary Parallel*, which the next real or mark't one shews to be the *Parallel*, for the 14. of *May* and 12. of *July*, and consequently by the Deviations of the *Aequinoctial Colure* that the then *Declension* is about 21 Degrees. In like manner you must have look't on the *West* side of the *Globe* if you would have had the time of the *Sun's setting* an hour later than 7; and thus you are still to operate when any other space of time is required.

OPERATION XIII.

To find the Sun's Amplitude, Ortive or Occasive.

BY the *Sun's Amplitude* we mean his distance in the *Horizon* from the true East and West Points at his Rising or Setting; so that this Operation is also a *Corollary* from the former; for, knowing (on the said 10. of *April*) the point or place where he Rises, you will find the *Ortive Amplitude* to be Northward from East about 18 Degrees, and (on the other side of the *Globe*) the *Occasive Amplitude*, to be Northward as much from the West.

OPERATION XIV.

To find the length of the Day and Night.

DOUBLE the hour of the *Sun's Setting* (which on the 10. of *April* happens, as we said, about 7 at night) and the Product (to wit near 14 hours) will be the length of the Day; or double (5) the hour of his Rising, and the Product (10 hours) gives the length of the Night. Nay, if you do but consider how the *Parallel of the Day* is cut by the *Horizon*, you have the whole business represented to the life at one view, even as it happens in the very Heavens themselves; for that part of the said *Parallel* above the *Horizon*, being divided to your hand by the *Hour-circles*, into almost 14 hours, shews the *Days length*, and consequently that part under the *Horizon* (shewing a little more than 10 hours,) gives the length of the Night.

OPERATION XV.

To find the beginning and end of the Crepusculum.

BY the *Crepusculum* is understood the *Twilight* which appears before the *Sun's* Rising, and continues after his Setting; for as soon as the *Sun* comes within 18 Degrees of the *Horizon* (according to the Opinion of the ancient *Astronomers*) or within 16. Deg. according to that of *Tycho*, and some Modern ones) his Rays are reflected from the *Atmosphere* or circumambient vapours, and consequently illuminates, so that this light still encreases, by how much the *Sun* approaches the said *Horizon*, and decreases as it recedes. Now to find it, you are to bring the *String* hanging on the *Zenith* to the *Meridian*, and making the *Bead* (if you follow the latter *Hypothesis*) to stand by the help of the *Quadrant of Depression*) at 16 Degrees under the *Horizon*, move it on the East side of the *Globe* along the *Parallel of the Day* (i. e. that of the 10. of *April*) till it just touches the said *Parallel*, under the *Horizon*, and there will be the true point of the *Morning Crepusculum*, which the adjacent *Hour-circle* tells you begins about 3 in the morning. In like manner if you move your *Bead* on the *West* or *Evening* side of the *Globe*, you will find it to end near 9.

OPERATION XVI.

To find the *Sun's* Depression at any time of the Night.

BY *Depression* we mean, how many Degrees the *Sun* is then under the *Horizon*, which is easily perform'd if you know the hour of the night, by the *Moon*, *Stars*, *Clock*, or the like; for finding (as hath been^a shown you) what part or point of his *Parallel* the *Sun* is then in, & where the *Hour-circle* (corresponding to the time of the night) and *Parallel of the Day* intersect, draw the *String* from the *Zenith* over it, and moving your *Bead* to it, bring the said *Bead* to the *Meridior Quadr.* of *Depression*, and then by the help of the Degrees there (reckoning from

^aOp. 6. pag. 11.

from the *Horizon* to the *Bead*) you have before you the required *Depression*.

OPERATION XVII.

To find the Sun's Right Ascension.

THE *Right Ascension* is that *Point* or *Degree* of the *Equator* cut by the *Meridian*, or *Hour Circle* that runs through the *Sun's* place in the *Ecliptic*; and this *Degree* is called the *Right Ascension*, because in the *Position* termed by *Astronomers* and *Geographers* the *Right Sphere*, (which together with the *Oblique* and *Parallel Spheres*, shall be farther explained in the * *Geographical Section*) it rises or *Ascends* with the *Sun*.

* *Vid. Oper.*
13. *Sect. 2.*

To find then the *Sun's Right Ascension* (a thing often of great Use) you are only to take the *String* (hanging from the *Pole*) and lay it on the *Degree* of the *Ecliptic* possess'd then by the *Sun*, that is to say upon the 1st. of 8 (for the 10. of *April* is still our Example) and the *Degree* of the *Equator* cut by the said *String* is the required *Right Ascension*, which counting from 7 or *East Point* (as you must always do) happens to be 28 *Degrees*, or thereabouts.

OPERATION XVIII.

To find the Ascensional Difference.

AS for the *Ascensional Difference* (i. e. the *Difference* between the *Right* and *Oblique Ascensions*) we have it here before our Eyes at a View, as being that portion of the *Day's Parallel* which lies between the *Sun's Rising* or *Setting*, and the 6 a Clock *Hour Circle*, so that if he rises on the 10. of *April* at almost 5. and sets near 7. we may conclude that the *Ascensional Difference* is about 14. *Degrees*, for 15. make an hour. But if you will be exact, then lay the *String* from the *Pole* on the *Point* where the *Sun* rises or sets, and when it cuts the *Equator*, count there the *Degrees* from the said *String* to the 6 a Clock *Circle*, and all is done. Thus then you see, that when we

know the *Ascensional Difference* we have the time of the *Suns* Rising and Setting, for it is but adding it to 6 a Clock, if the *Sun* be in his *Northern Declension*, or subtracting it in his *Southern*.

The E. N. D. of the first Section.

SECT. II.

Of the Operations that concern Geography.

*Preliminary
Considerations*

HAVING given you a short account of the *Operations* immediately relating to the *Sun*, without reflecting upon any part of the *Earth*, but that, on which we then stand, wee'l now descend to those that concern *Geography*, where you may have a view not only of all *Countries*, as to their *Situations*, *Extent* and the like, but see at one glance when you please, several other things appertaining to them worth the knowing, as, *What a Clock it is in any place imaginable; what People are Rising, who are going to Bed, and who to Dinner; as also, where it is they have no Night, where no Day*, with divers particulars of the same nature, which were thought by many formerly not performable without Magic.

That our Instrument is *Geographical*, no body will (I dare say) doubt, it being the *Terrestrial Globe*, and consequently the *Epitome* of the very *Earth* it self; and besides its many other *Operations* it may be perchance useful in this, that all *Countries* are here more obvious, and consequently more easily found out than in any common *Universal Map* or *Globe*. Nor do's it a little contribute to it, and fix the *Pcition* and *Order* of the said *Countries* in our *Memory*, that not only the *Divisions* and *Subdivisions* of the *Earth* are (by our present *Directions*) clear and distinct, as far as this small bulk can afford, but freed also from the usual crowd of *Towns* and *Places*, very often neither of *Note* nor *Use*, unless for *Distraction*. For the

the business of a Terrestrial Globe, is to represent the situation of famous Regions and Provinces, and how they are distant each from the other; to show us also where the late Discoveries are; where more may chance to be made; what proportion any Place bears to the known Parts, or they to the whole *Terraqueous Mass*. These (I say) and the like, are what a Globe is properly to represent; for small and inconsiderable Places ought not to be there, as being the chief Object of *Chorographical* and *Topographical Charts*, to which the curious are to recur upon occasion.

As for the first or grand Division of this Globe, to wit, the four *Quarters*, their names are in the midst of them in remarkable Capital Letters; nor is there any trouble about their *Bounds*, after that that joyns *Europe* and *Asia* is consider'd; for bating the little Isthmus made by the *Mediterranean* and *Mare rubrum* (which contains the limits of *Asia* and *Africa*) there is no part of the said *Quarters*, which is not surrounded by the Sea. For the separation then or Boundary between *Europe* and *Asia*, it is a fine black line, that beginning at the mouth of the *Tanais*, runs up the Stream to *Tua* (situated on its most Easterly Flexure,) and thence going to the nearest Banks of the River *Oby*, accompanies it till it falls into the *Northern Ocean*. This I say is the separation drawn by me, and not from *Tua* to the mouth of *Duina* at *Archangel*; for since there are (as to the Question in hand) different and various Opinions among *Geographers*, I follow the rather this Division than any other, since it contains almost all the vast Dominions of the *Russian Emperor*, and so makes him as it were an intire *European Monarch*.

The Division of each modern Country from the other (which have all their Names on them in small Capital Letters) is also a black prick line, and that you may have a glimpse also of *Antient Geography*, I have express'd some of the most considerable old Nations and Empires, by Prick Lines of several colours (as the directions on the Globe it self shews you) to amplify or contract their Bounds, when they agree not with the present Limits; but as for *Cities* and *Towns*, there are (as I said) but very few of any sort set down, for in all the *Island of Great Britain*, we mention but *London* and *Edinburgh*, besides a *Port* or two, in which proportion we proceed all along.

Thus:

Thus having acquainted you with these few *Preliminaries*, we'll now, after you have a little consider'd the Names of each *Country*, and how they all lye from your *Zenith*, where you are ever to suppose the *Country* or *Place* to be, which the *Globe* is made for; I say, we will now, after you have a little considered these things, fall upon the *Operations*, an Employment commonly much more diverting and pleasant than *Speculation*.

OPERATION I.

How to find the Distance between any two places.

IF the Question be (for Example) between *Constantinople*, and the *Place* you dwell at, (which we shall for the Future suppose still to be at *London*) Draw your *String* from the *Zenith* streight over *Constantinople*, and having mounted your *Bead* thither, bring it to the *Meridian*, or *Quadrant of Altitude*, and it will lye (counting from the *Zenith* to it) on the 24 Degree, or thereabouts, which multiply by 60 (the number of *Miles* contained according to the Common Account in each Degree) shews you that the Distance required is some 1440 *Miles*. But if it be demanded how far it is from *Constantinople* to *Tangier*, i.e. from any other two Places, when neither lye under your *Zenith*, then take a pair of *Compasses*, and placing one Foot on the first Town, and the other Foot on the second, find (in the *Meridian*, *Aequator*, *Horizon*, or any other divided great Circle) the Number of Degrees between the Feet, which making about 31. amounts to near 1860 miles. Or if you have no *Compasses*, fix the loose or Plummets-end of your *String* with your Finger on *Tangier*, and drawing the rest of it streight over *Constantinople*, place there the *Bead*, and if you measure that distance in any of the said divided Circles it will give you the above-mentioned Degrees and Miles.

A Table of reducing Degrees into Miles.

And here be pleased to remember that to free you from Multiplication in Relation to Miles, I have ordered a little Table to be plac'd in the vacant part of the *Globe* towards the *Southern Ocean*, where you may find from 1. Degree to 20. how many Miles any number of Degrees give; but if your Question con-

tains

rains more Degrees than are set down, as for Example 31. you are only to add 660. (which you will see in the Table is the value of 11. Degrees) to 1200 (the value of 20.) and the *Sum Total* makes 1860. Miles for the required distance. In this manner you must operate in other cases.

The Table of *Reduction* is to be in the following manner.

| | | | |
|---------|-----|---------|------|
| 1 ---- | 60 | 11 ---- | 660 |
| 2 ---- | 120 | 12 ---- | 720 |
| 3 ---- | 180 | 13 ---- | 780 |
| 4 ---- | 240 | 14 ---- | 840 |
| 5 ---- | 300 | 15 ---- | 900 |
| 6 ---- | 360 | 16 ---- | 960 |
| 7 ---- | 420 | 17 ---- | 1020 |
| 8 ---- | 480 | 18 ---- | 1080 |
| 9 ---- | 540 | 19 ---- | 1140 |
| 10 ---- | 600 | 20 ---- | 1200 |

OPERATION II.

How to find the Latitude and Longitude of any Place.

The Latitude of a Place is its nearest distance from the *Æquator*; If therefore you would know the Latitude of, (suppose) *Constantinople*, draw the String from the Pole over the said City, and placing thereon the *Bead*, bring it to the gradual division of the *Colurus Equinoctiorum*, or 6 a clock Hour Circle, and it will lye on the 43 Degrees, and about 5 minutes more, for the Latitude required. *What the Latitude of a Place is, and how to find it.*

The Longitude of a Place is the number of Degrees (reckon'd Eastwardly in the *Æquator*) from the grand Meridian to the Hour Circle, or particular Meridian that passes through the Place required. *What the Longitude is.*

As for the said Grand or General Meridian, 'tis that from whence we begin our Reckoning; and since it matters not (as you will plainly see in the Memorandum of the third or following Operation) where we commence, to wit whether from the *Of the Grand Meridian.*

Me-

Meridian that runs thro' *London*, or that thro' *Paris*, *Rome* or any other place, if people be acquainted with it before hand; I say, since this is so, what wonder is it, (there being by reason of some accidental Proprieties and Causes infinit fit Places) if *Geographers* and other Learned men quarrel in the Affair, and earnestly strive to have the Prerogative granted that *Countrey*, which they are pleased to propose.

Of the most
noted Places
where Au-
thor's have
plac't the
grand Meri-
dian.

Of all places, the *Hesperides*, *Azores* and *Canaries*, (by reason of their *Westerly Site*, or the pretended non-variation of the *Needle* in some of them) have had the most vogue; but since each of the said Places make not one but many *Isles*, they afforded new occasion of Dispute; for among the *Hesperides*, or *Isles of Cape Verd*, some would have *Fuego* to carry away the Bell, some *St. Nicholas*, but others *St. Vincent*, as appears by *Hondius's Globe*. Now *Langrenius*, in his, begins from *St. Mary* and *St. Michael* in the *Azores*; *Johansonius* in his *Universal Map*, counts from *Corvo* and *Flores*, whereas the Learned *Dudley* (the late *Titular Duke of Northumberland*) gives the honour to *Pico*, and has as much reason for it as the rest. Nor is there less do about the *Canaries*, for the *French* fix it at *Ferro*, several of the *Hollanders* at *Teneriffa*, and many other Nations at *Palma*, which is the Place I would willingly choose, (since the great *Ptolomy* thought fit at last to assign it there) were it as convenient for my present purpose as *St. Vincent*.

Where we fix
our Grand
Meridian.

'Tis *St. Vincent* then I here pitch upon for this *Meridian* to passe throu', because it differs in *Longitude* from *London* within less than 10 Minutes of just 30 Degrees, or 2 Hours, so that the 2 a *Clock Circle* will represent it (within almost a Minute in time) without need of drawing a Particular one, and the said *Meridian* is (as I told you in the beginning) distinguished from the rest by Pricks, which being distant from each other a quarter of a Degree, are useful on several occasions.

How to find
the Longitude
of any place.

Having thus fixt our *Grand Meridian*, or first *Longitude*, that of other Places follow's with ease; for if you would know the *Longitude* of *Constantinople*, draw but your *String* from the *Pole* over it, and it will cut the *Aequator* neer the 62. Degree for the *Longitude* required, as you may readily percieve by the lower little *Aequinoctial Figures*.

OPERATION III.

How to find out any Place, the Longitude and Latitude being given.

THis Operation is not only usefull for the finding out of Towns express'd on the *Globe*, when you cannot guess whereabouts they are situated, but also for the placing them truly in case they should chance not to be set down. Suppose then *Constantinople* were the Town sought for, and that you found its *Latitude* to be 43 *g.* 5'. and *Longitude* 61 *g.* 46'. in some book or *Geographical Table*; I say supposing this, you have nothing to do, after having mounted your *Bead* (by the help of the devided *Colurus*) 43 *g.* 5'. above the *Aequator*, but to move your *String* on its *Noose* from the *Pole* to 61. 46. in the said *Aequator*, and *Constantinople* will be just under your *Bead*; and if (in case of Omission) it should not, you may then if you please marke it out your self, for that is its exact place.

But by the way, if the *Geographical Tables* agree not with the *Longitude* of your *Globe* as telling you that (*v. g.*) *Constantinople* has but 54 *g.* 36', you are then to look from whence the said *Tables* begin, and finding their Commencement, suppose at *Palma*, and that *Palma* (according to the former Operation) has by your *Globe* 7 *g.* 10'. of *Longitude*, you must add this number to your *Tables*, and then you will agree.

OPERATION IV.

To find the situation of any Place according to the Angle of Position, or Points of the Compass.

Draw the *String* from the *Zenith* over, *v. g.* *Constantinople*, and 'twill cut the *Horizon* about 5 Degrees beyond *E b S* Eastward, for the true situation of the said Town from your Habitation, according to the Points of the Compass.

OPERATION. V.

To find in what Clime or Parallel any Place lies.

A preliminary
Discourse of
Climes.

BEfore we can here well come to *Operation*, there are some few Particulars to be consider'd; and first what a *Clime* is; which is no hard thing to conceive, since most know that after the *Vernal Equinox* our Days not only exceed 12 hours, but that every nearer Countrey to the *Pole* has days of greater Length than the Remoter: Nor are there many ignorant, that when our Days (that live on this side of the *Line*) increase, theirs on the other side decrease proportionably, and when theirs encrease ours decrease; so that no People are at a Constancy, but they that dwell exactly between both *Poles*, to wit under the *Equator*. This Diversity was thought by the Ancients a thing so fit to be known, that they invented the Division of the Earth into *Climes*, so that as soon they heard a Countrey named, they presently (besides the fond Reflections concerning the Temperament of the *Air*, Ingeniety of men, &c.) knew the length of its longest Day, and consequently how much any other Place exceeded or came short of that length.

For suppose the first *Northern-Clime* were to pass over all the Places on this side of the *Equator*, whose longest Day is 12 hours and $\frac{1}{2}$; and the second *Clime* those of 13 hours, and so on towards the *Pole* by a half hourly Increment, what difficulty could there be to resolve immediately the Question, when we once know the *Clime*, or having the length of the longest Day to find out the very *Clime* it self.

I wonder therefore, that so ingenious a man as *Delisle*, should seem to assert, that this Division is useless; it being as easy to find the longest Day as the *Clime*; whereas, were *Climes* in esteem and fashion, the Memory would as soon conceive and remember in which of them any Countrey lay, as now it does its Bounds, the manner of its situation, and the like; and if so, one may quickly judge whether they are useless, and whether it be possible that the length aforesaid can be known by any other means so universally, and at so easy a rate.

A Clime then (generally speaking) is a Space contained between two Circles Parallel to the Equator, having the Places thro' which they pass differing (as to the length of their longest Days) half an hour; and this Space takes the name of Clime from *Kλίμα* *Inclinare* vel *Deflectere*; for the greater our Deflection is from the Equator or Right Sphere, the longer our Summer Solstitial Day will be. Nor were the Antients content with this large Devision of the Earth, but subdivided it into *Parallels*, so that Places differing a quarter of an Hour, were reckon'd to be under such and such *Parallels*, which some call *Artificial* (from their relation to the *Artificial Day*) to distinguish them from all others that occur.

What a Clime
n.

What a Parallel
n.

As for the Antiquity of Climes, 'tis immemorial; nor could there be many in the beginning by reason of the small extent of the known parts of the World; For tho' *Ptolemy* reckons about 10, that is to say 21 *Parallels*, as making them to reach as far as *Thule*; yet *Homer*, *Ovid* and other Poets, so possess'd men with the Fancie, that from the *Cimmerians* Northward, there was nothing by reason of the hideous vapours and exhalations, but a dubious and creperous light, that even *Pliny*, and after him the *Arabians* insist'd only on seven, looking on all Countries that lay farther as not worth perchance the taking notice of.

Of the Antiquity and number of Climes.

As for the seven in vogue with them, and mention'd also very particularly by our Countryman *Sacro-bosco* (whose credit and great Repute has perchance not a little kept up their Fame among the Moderns) they were, *Dia-Meroos*, *Dia-Syenes*, *Dia-Alexandrias*, *Dia-Rhodon*, *Dia-Romes*, *Dia-Boristhenes*, and *Dia-Riphaeon*, being all names made by the Addition of the Greek Preposition *Dia* (i.e. *per*) to some remarkable Town, River, or Place, thro' which the middle of each Clime pass; so that the middle of the first went thro' *Meroe*, an *Ethiopian* City on the *Nile*, where (according to some) *Queen Candace* Reigned; the second thro' *Syene* in *Egypt*, lying just under the *Tropic*; the third thro' *Alexandria*; the fourth thro' the *Ile of Rhodes*; the fifth thro' *Rome*; the sixth thro' the mouth of *Boristhenes*, now called *Nieper* by the *Cossacks* and the other Inhabitants; and the seventh and last thro' the *Riphaean Hills*, part of which lay according to their account in

Of the 7 common Northern Climes.

or about, the *Latitude* of 50 Degrees, and consequently corresponded with the *Cimerians*.

Of the 7 Southern Climes.

It was here then that *Alfraganus* and other *Arabians* ended Northwards, who besides several small particulars, err'd not a little in making *Rome* and the *Boristhenes* only a *Clime* asunder, when as their longest days differ at least an hour. And as for the Southern *Climes* (to wit those on the other side of the *Equinoctial*) they thought fit to consider them, but not knowing what to call them, as being ignorant (for the most part) of the Places they went through, they added *'Arri* (i. e. *Contra*) to the former Denominations, so that making *Antidia*, *Meroes* serve for the first *Clime*, *Antidia* *Sienes* for the second, they proceeded in the same order with the Rest.

Why the middle of the first Clime has 13 hours of day.

But now before I end, I shall endeavour to solve a difficulty which startles not a few, viz. how it comes to pass (seeing the *Climes* are assigned (as we mentioned) by the Antients, to know the length of the *Summer Solstitial day* in every Country) that the middle of the first *Clime* (which in rigour should lye no further from the *Aequator*, than to encrease the day a quarter of an hour) runs over *Meroe*, where the Excess is at least an hour. I answer, the *Antients*, deeming it more equal that the middle of the *Clime*, and not the end of it should be the Point where the half hourly increment was to begin, fixt the *Terme à quo*, not in the *Aequator*, but a quarter of an hour further, and therefore *Taprobane* (which some now think *Sumatra*) was the place where *Ptolemy* commences all his *Climes*, making thereby the middle of his first to pass per *Sinum Avalitum* or (Mouth of the *Red Sea*) and the middle of his second per *Meroen*; But the *Arabians*, thinking that for several Degrees from the *Aequator* all was either Sea, or (by reason of the Heats) scarce Habitable, or else judging it for their Honour, to have their own Country in the first *Clime*, began half an hour beyond *Taprobane*, and so *Dia Meroes*, (tho' the Days are there 13 hours long) leads the Van in their Catalogue.

How the first Circle of Longitude is divided as to the Climes.

These few things premis'd, I shall now shew you the way I take therein, which I think in all respects clear and ready. First, I make the *primary Circle of Longitude* to be the Circle particularly appropriated to this use, being divided and mark't according to the true distance of each *Clime* from the other; and as to the place where they commence on our *Globe*, I rather fol-

fol-

follow *Ptolemies Astronomical* than *Geographical Method*; for (besides the aforementioned excess of the *Arabians*) should we begin but a quarter of an hour from the *Equator*, it makes a great space of the Earth, *viz.* from *Taprobane* to the *Equator*, to be in no *Clime* at all; and which is more, it causes a little confusion, when the length of the day is greater in every *Clime*, than what the said *Clime* can justly challenge, according to its Rank and Number; I say, as for the place where the *Climes* commence, I rather follow *Ptolemies Astronomical* than *Geographical* way; and therefore beginning at the very *Equator*, my first *Parallel* (or middle of my first *Clime*) is supposed to run over the places that enjoy 12. hours and a quarter of Day, and the end of it (noted on the primary Circle of Longitude or 2 a Clock Hour Circle with the Figure I.) over the places that have 12. and $\frac{1}{4}$; and thus we proceed to the Polar Circles, to wit, where the 24th. *Clime*, or 48th. *Parallel* terminates, so that from thence we come to the Deviations on the said Circle of Longitude, which show where the days are as long as an ordinary Week, where as long as a Month, and where as two, arriving at last at the Poles themselves, where there is a constant half year of light, and as much of Darkness. And to give you a Remembrance of the Names of the aforesaid old *Climes*, and that you may also see without Calculation or Trouble where the *Ancients* plac'd them, I have set down the first Syllable of their names (as *Mér. Sy. Al. &c.*) according to their respective *Latitudes*.

To find then in what *Clime* any place is (*v. g. Constantinople*) you are only to draw your String from the Pole over that City, and mounting up the Bead thither, to move it to the said Primary Circle of Longitude, and 'twill lye on the *Clime* or *Parallel* required. But if you would know what places are (suppose) under the 4th. *Clime*, throu'out the World, *i. e.* what places have their longest day just 14. hours; Fix the Bead on the 4th. *Clime* and moving it on its Noose from the Pole round the Globe, you may conclude that every place it passes over, has the Sun exactly so long above the Horizon, when the days are at the longest; and in the same manner you must proceed on the South of the *Equator*, to find the Countrys that lye under the 4th. Southern *Clime*. In short, here we have, besides (what has been already said) a view not onely of the strange inequality of the *Climes*, (especially between the first and last) but also of their exact distance

To find in what *Clime* any Place lies..

Of the inequality of the *Climes*.

* pag. 23.

Of the 5
Zones.

Of the bounds
of the Torrid
Zone, which
contains the
Amphiscii,

To find when
the shade
changes side
here.

Of the
bounds of the
frozen Zones
which con-
tain the Pe-
riscii.

Of the
bounds of the
Temperate
Zones which
contain the
Heteroscii.

stance in *Degrees*, and consequently in *Miles*, by help of our Table of *Reduction*, mentioned in the first * *Operation* of this Section.

But seeing we are a little fallen into Speculation, 'twill not be, perchance, improper to proceed yet further, and to consider here, as in a natural and fit place the Bounds and Terms of the five Zones, so called from *Zon* *Cingulum*, as enclosing the whole World within their respective Districts: 'Tis with the *Torrid* one we'll then begin, whose Bounds are the two *Tropics*, so that the *Diurnal* *Parallels* not only remarkably distinguish it from the other Zones, but shew why the several Inhabitants within this space were called by the Ancients *AMPHISCII*, i.e. *Utrisque umbrati*, or men that had two shadows, from *Am* *utrinque* & *Utra Umbra*; nay, by the said *Parallels* you may find when the shade will change and be different; For, since by these Paths or Traces the *Sun* (as we often hinted) passes from *Tropic* to *Tropic*, 'tis evident: that sometimes he must be on the Northside and sometimes on the Southside, of all that live here, which must then needs alter the shadow. And as for knowing the time of this change, we are only to consult the days of the Month on each *Parallel*; for that which passes over the Heads of the propos'd Inhabitants, shews that from that time to the 11. of *June* (or the *Sun's* coming to *Cancer*) and so till he comes again to be *Vertical*, their shade will be full *South* at noon: whereas from his said *Vertical* station to the 11. of *December* (when that he enters into *Capricorn*) and so till he comes again to them, their shadow will be directly *North*.

From this *Torrid* and hot Residence, we'll now run to the other Extream, viz. to the two *Frozen Zones*, which lying from each *Polar Circle* to the very *Poles* themselves, are sufficiently distinguish'd from the rest.

Now since the longest day within these Limits is at least 24. hours in length (as we shew'd you even now in treating of the *Climes*) and since the *Sun* in this space of time, compasses the World, it must follow that here he runs round the Inhabitants, which gave the name of *PERISCII* to them, that is to say *Circum Umbrati*, or surrounded with their shadow, from *Per* *Circum* & *Utra Umbra*.

As for the two remaining Zones, they are the *Temperate* ones, bounded by the *Tropic's* and *Polar Circles*: Nor do the Inhabitants

habitants of this moderate and more excellent position want an appellation from the property of their shadow also; for never having the Sun but on one side of them (as still setting before he gets round) and unable to pass, as he could in the *Torrid Zone* over their Heads, by reason he has no excursion beyond the *Tropics*) it must needs follow that their shade who live in the *Northern Zone*, will ever fall North, and theirs in the *Southern*, South; so that they were called *HETERO SCII*, i. e. *Habenis alteram solum Umbram*, or People having but one kind of shadow, from *ἕτερος* alter & *ἑξία* Umbra.

So much then for the *Climes* and *Zones*, together with their various inhabitants, and now we will proceed to the Operations that follow.

OPERATION VI.

To know what a Clock 'tis at any time, in any place of the World.

THERE is no Operation perchance in the whole *Treatise*, First way. more diverting and pleasant than this; nor scarce any more readily perform'd after a very little Reflection, even in the most difficult Cases. For having Compos'd your *Globe*, if it be then 12. a Clock with you, the *Standing Hour Circles* or *Meridians* already described, will (by the *Common* or *little Figures* which lye within or upon the *Roman* ones, that surround the *Polar Circles*.) shew you exactly the *Hour*, wheresoever you cast your Eye; That is to say, that 'tis about 2. of the Clock at *Constantinople*, 12. at *Athens*, &c. But now, if it be not 12. with you; but (v.g.) 3. in the afternoon, when you desire to know the then hour at *Constantinople*, add the said 3. a Clock to the Figure 2. (which you see lyes, as I now mention'd on the *Midian* or *Hour Circle*, that runs near that City) and 'twill tell you that 'tis about 5. a Clock there; and thus you must always do, unless the time of the Day with you, and the Figure that lies on the *Midian* of the place in question make a greater number than 12; for then the Hour sought for, is what remains above 12; as for Example, if it be 11. with you, then this with 2. (i.e. the Figure near the *Midian* of *Constantinople*) making

13. do but cast away 12, and you may conclude it there 1 in the Afternoon.

Second way.

There are several other ways of performing this Operation; as finding the Difference of Longitude between you and the Place in Dispute, and so adding or subtracting it (as need requires) from the true time of the Day, Or else by calling

Third way.

it always *Mid day* there where the *Hour Circle* that shews your then true time of the Day (which by our Example is 3 in the Afternoon) crosses, for by counting from thence to the *Meridian* of the Place in question, either forwards or backwards (as 1, 2, 3, 4, or 11, 10, 9, 8, &c.) according as the said Place lies East or West from 3, and all is done; I say there are several ways to perform this Operation, but seeing the first is the most clear and expedite, I solely insist on it: and now because you may be perchance running over with your Eye, the whole *Globe*, and considering how one Situation or Country differs from another in time, 'twill not be amiss to tell you that there are 3 *Places*, that have more particular Relation to your Dwelling or Habitation than any other.

Of the Peria-
ci.

The first is that, which lies opposite to you in your own *Parallel*, whose Inhabitants are called by the Antients *PERIÆCI*, or *Circumcola*, from *per* Circum & *cola* inhabitato, and though by the Word, all People are comprehended that dwell any where in the said *Parallel*, yet *Geographers* commonly mean those by it, that are thus Diametrically situated. These then live in the same *Zone* and in the same *Clima*, and cast the same kind of *Shade* with you: These enjoy your proportion of *Heat* and *Cold*, your *Seasons of the Year*, your *Increase of Days* and *Nights*, and in short all things else of this kind, saving that your *Hours* are opposite; their fix in the Evening being your fix in the Morning; and your Noon their Midnight.

Of the Anteci.

The Second Place lyes under your very *Meridian*, or in the *Clock Hour Circle*, which makes your *Hours* and theirs the same, but by being 51 8 30' on the other side of the *Equator*, it happens that tho you all agree in the Temperament of your *Zones*, number of *Climas*, in the Casting a *Shadow* on one side only, and the like; yet their *Zone* and *Clima* are Southern, their *Shade* falls toward that *Pole*, their *Summer* is your *Winter*, and your *Spring* their *Autumn*; so that from this contrariety

trariety they are named *ANTÆCI* or *Adversicola* from *anti contra*, & *intra Habito*.

The Last is the *Nadir* or Point on which the *Globe* stands, whose Inhabitants are called *ANTIPODES*, i.e. *opposita habentes vestigia*, or men that walk Feet to Feet with you, from *'Anti Contra*, & *Prope Pedes*. These imply (even by the vulgar acception of the word) the height of Opposition; and since they are the very *Antaci* of our *Periaci*, participating thereby of whatever was opposite to you in either of the former *Places*, it is no wonder that you enjoy together neither *Day* nor *Night*, nor *Season* of the *Year*, nor any thing else of this Nature.

OPERATION VII.

To find where 'tis Day, and where 'tis Night, all the World over.

Compose your *Globe*, and all People that live in the illuminated Hemisphere, enjoy *DAY* at that Moment; and all that live in the *Obscure One*, *NIGHT*.

OPERATION VIII.

To know where at that Moment of time the Inhabitants enjoy nothing but DAY, and where nothing but

NIGHT; as also when the DAY and

NIGHT will be thus perpetual in any place subject to this Alteration.

Describe with your Eye an Imaginary Circle about the Illuminated Pole, its Radius being the Distance from the said Pole to the nearest part of the shade of Extuberancy, and all places within that Circle will have then no Night, and all places within the dark Circle of the like Radius, round the obscure'd or obumbrated Pole will have then no Day: Now if you desire to know, when 'twill be in this manner perpetual Day or Night, at any Place between the Poles and the Polar Circles,

F

(for

(for you know 'tis never *perpetual Day and Night* any where else) you have nothing to do but to measure with your *String*, or *Compasses* the Distance between the Place requir'd and the next *Pole*, which now for Examples sake, we will suppose the *Northern Pole*; I say you have nothing to do, but to measure this Distance; for placing one end of your *String*, or one *Foot* of your *Compasses* on the Intersection of the *Meridian* and the *Equator*, if you observe what *Northern Parallel* the other end of your *String*, or *Foot* of the *Compasses* (extended at the aforesaid Distance) touches, 'twill shew you by touching (v. g.) the *Parallel* mark't with the 20th. of *April*, and 12th. of *July*, that it begins to be on the said 10th. of *April*, *perpetual Day* there; and so continues until the 12th. of *July*. Now if you measure from the before mentioned Intersection towards the *Southern Pole*, and find the End of your *String*, or *Foot* of the *Compasses* to touch the 13th. of *October*, and 9th. of *January*, 'tis certain that from the said Day in *October* to that of *January* 'twill be *perpetual Night* there, and consequently from the 12 of *July* to the 13th. of *October*, the *Days* and *Nights* succeed each other after the ordinary manner.

OPERATION IX.

To find where the Sun is Rising, and where He is Setting,
all the World over.

Compass your *Globe*, and having consider'd the Confines or Extremity of the PRECEDING and FOLLOWING *Shades of Extremacy*, you may conclude that to all the Inhabitants under the first, the Sun is *Rising*, and to them under the Second, that He is then *Setting*.

OPERATION X.

To find where the Sun is Vertical at any time, i.e. what People have him just over their Heads.

THE Sun is always Vertical to those that lye in the middle of the Illuminated part of the Globe, i.e. to those that dwell under his then present Place in his Parallel; therefore (as I show'd you in the * first Section) if you Compose your Globe and * Op. 6. pag. hold up your String against the Sun from the Pole, till its Shade passes thro' the other, or from the Zenith, till it passes thro' the Nadir, 'twill cut the Parallel of the Day at the Sun's true Place, and consequently show you who they are, that have him then just over their Heads; which happens (for Examples sake, on the 10th. of April, about our 6 in the Morning) to them that dwell about the middle of the Coast of Malabar.

OPERATION XI.

To know where they are Rising, where they are at Dinner, where at Supper, and where going to Bed all over the World.

THIS Operation depends on this Maxim, That it is the same Hour with all People that have the same Longitude, that is to say, that live under the same Semi-hour Circle, or Semi-Meridian, therefore as the drawing of your String from the Pole, over half the illuminated part of the Globe, i.e. over the Sun's present Place, shows you that 'tis Noon or Dinner-time with all that inhabit under the said String, so the drawing it over any Place distant 6 hours Westward (i.e. over so many hours towards the left hand from the Vertical point) shows where 'tis then all the World over 6 in the Morning, or Time to Rise; whereas had you drawn it six hours Eastward (i.e. towards your Right-hand,) it would have shown you where 'twas six in the Evening or Supper-time, and four hours further (i.e. where 'tis Dinner-time all the World over. where 'tis Supper time all the World over.

Where 'tis
Bed-time all
the World o-
ver.

two hours short of *Midnight*, or the point opposite to *Noon*
where 'tis 10 of *Clock*, or *Bed-time*.

OPERATION XII.

How much any People (if it be Day with them) are past Morning, or want of Evening; and (if it be Night with them) how much they are past Evening or want of Morning.

IF the *Place* you propose has a *Diurnal Parallel* that runs over it, then see what *Point* of the said *Parallel* the *Preceding Shade* of *Extuberancy* cuts, and if you count the *Hour Circles* or distance in time between the said *Point* and the proposed *Place*, 'twill give you (if it be there *Night*) how much it lack's of *Morning*; and the distance in time between the said *Place* and the *Point* made by the *Following Shade* of *Extuberancy* gives you how much it is since *Evening*. On the other side, if it be *Day* there, the distance between the said *Place*, and *Point* made by the *Preceding Shade* tells you how long 'tis since *Morning*, and the *Following Shade* how long 'tis since *Evening*. Now if there be no *Parallel* that run's over or neer your said proposed *Place*, mount your *Bead* to it, and moving your said *Bead* on the *Noose* from the *Pole* it will describe a *Parallel*, and then you may operate as before.

The Reason or
Demonstration
of the O-
peration.
* Oper. 10. §12.
L. pag. 14.

The Reason of the Operation is this; The *Shade* of *Extuberancy* getting every hour in the *Aequator* (as you saw * before) fifteen degrees, 'twill proceed in the same proportion on all *Parallels* over, which it passes, therefore, if the Distance between any *Point* in the *Aequator* and the *Following Shade* be the distance in time of the said *Point* from *Evening* or *Sun-set*, and if the distance there between any *Point* and the *Preceding Shade* be the distance of the said *Point* from *Morning* or *Sun-rising*, it follows that the distance between any *Point* in an *Aequinoctial Parallel* and these two *Shades* of *Extuberancy* that cut it, must be also it's true measure or distance in time both from *Morning* and *Evening*.

OPE-

OPERATION XIII.

To find the Sun's height in any Place, where the Globe shews 'tis Day, or his Depression where it shew's 'tis Night; as also what People throughout the World see the Sun, at the same Height.

Suppose on the 10 of April (Having compos'd your Globe, and found it about 6 in the morning with you) you should desire to know how high the Sun is at Rome, as also all the People that then see him at that, or any other determin'd height, Measure by your String or Compasses, the nearest Distance between Rome and the shade of Extuberancy, and 'twill give you in any great Circle about 22 Degrees for his Height there at that moment. And the reason of it is, because when the Sun (i.e. the Place where he is Vertical) is distant 90 Degrees from Rome, then Rome sees him in his Horizon, and as soon as he gets above the Horizon (v.g.) 22 Degrees, his Rayes will illuminate beyond Rome 22 Degrees; for else there would not be always 90 Degrees from the Place where the Sun is Verticall to the Confines of the shade and Light, or utmost Extent of his Rayes; but the distance from Rome to the nearest part of the shade of Extuberancy, is the distance of his Illumination beyond Rome ergo 'tis his true Height.

To find the Sun's height in any place.

The Reason of the Operation

In like manner if it be Night at any Place on your Globe, and you desire to know how much the Sun is there depress'd or under the Horizon: take the Distance (as before) between the said place, and the nearest Term of the shade of Extuberancy, and that (for the former reason) will be the required Depression.

To find the Sun's Depression.

As for the finding out of all Places, that have the Sun (suppose 22 Degrees above their Horizon, you are only to lay the Plummets end of your String or Foot of your Compasses on the middle of the Coast of Malabar (where we now suppose the Sun to be Vertical) and making your Bead or the other Foot of your said Compasses to lye on Rome, describe an imaginary Circle; and then all People under the said Circle will have the

To find all the Places, that have the Sun at the same height.

the Sun 22 Degrees high, since they are all distant from him like Rome; and thus you must operate in all other Cases.

OPERATION XIV.

To know what a Clock 'tis with you, the Italian, Babilonish, and Judaic way.

How Astronomers begin their Computation of Time

How the Italians.

How the Babilonians.

To find the Babilonish and Italian hour when the Sun is in the Equator.

** Op. 10. sec. 1. pag. 14.*

To find the Italian Hour when the Sun is in the Equator.

YOU are first to know that as England, France, Spain, Denmark, Sweden, most part of Germany, and many other Places follow the *Astronomical* account in their Diurnal Computation of time, with this only difference that the *Astronomers* begin at Noon, and so go on from 1 to 24; whereas the afore-said Nations begin at *Mid-night*, dividing the whole *Natural Day* into twice twelve hours; I say, as these Nations begin their Account at *Mid-Night*, so the *Italians* do theirs at *Sun-set*, continuing to 24 without interruption, after the *Athenian* manner of old, which is also now usually observed in *Bohemia, Austria, Silesia, &c.* On the contrary some Places in Germany, and particularly *Nuremberg*, still follows the ancient *Babilonian* or *Caldean Way*, as commencing their 24 hours from *Sun-rising*: therefore the difficulty and seeming Confusion of counting by either of these 2 last wayes proceeds from the *Sun's* inconsistency in its *Rising* and *Setting*; for when he is in the *Equinoctial* our *Globe* show's us the hour, as soon after their manner as our own: As for example, if you would then know what hour 'tis with you, the *Babilonian* way, Hold up your *String* against the *Sun*, and moove it on it's *Noose* from the *Pole*, till the shade fall on the contrary *Pole*, (i.e. look what a clock 'tis the * second Way, and where the shade of the *String* cuts the *Equator*, the *Roman Figures* there will give you the true *Babilonish Hour*. Or (which is all one) see what a clock 'tis by the shade of *Extubercancy*, or * 3d way, and finding the said shade to fall, suppose, on the 9 a clock *hour-circle* in the *Equator* as the then true hour after our *English Fashion*; do but cast your Eye on the *Polar Circles*, and the said 9 a clock *hour-circle*, will cut there at the *Roman Figure 3*. so that you may conclude it then 3 a clock the *Babilonian* way. Nor does the *Italian* runner

materially differ from this; for 'tis but adding 12 hours to the 3 found as before, and then 15 will be the true hour after that account.

Now if you would know the hour when the *Sun* is out of the *Aequator* (as for example, on the 10th. of *April*) consider the *Parallel of the Day*, which giving you at first sight about one hour for the *Ascensional Difference*, (as I shew'd you in the former * Section) do but add this hour to the three found, as we now shew'd you, and 'twill give you four for the true *Babilonian* hour; whereas if you substract it from 3 (i. e. from the aforesaid 15,) you have the true *Italian* hour; and thus you are to proceed in all other cases; Only remember that when the *Sun* is in his *Southern Declension* the Substraction of his *Ascensional Difference* gives the *Babilonian*, and the Addition of it the *Italian* hour.

To find the hour both the said ways at any time.

* Op. 18. p. 19

But if you would have yet an easier way of performing this, consult the 12th. Operation, and the distance in time there from Day gives you the *Babilonian*, and the distance from Night the *Italian* hour.

As for the *Jews*, they divided the day always into 12. equal parts, which they called hours, as appears by our *Saviours* demand; *Are there not 12 hours in the Day?* therefore when the *Sun* is in the *Aequator* (as it happened about the time of the *Passion*) this and the *Babilonish* way are the same, for then the 3d. hour is 9 a Clock with us; and our 3 in the afternoon is their 9th hour; so that at 6 our way, or at 12 theirs, the *Sun* Sets, and the Night begins, which they also divided into 12 equal parts; I say, this is the same as the *Babilonish* way, when the *Sun* is at or about the *Aequator*, and consequently easy; but afterwards, by reason of the strange inequality of both Day and Night, the *Computation* must be troublesome, especially if we use *Reduction* (the common prescribed way on the *Globe*) for the Summer days with us contain above 16 of our hours, and the Winter ones not half so many, and yet both kind of Days are to be divided into 12. equal parts or hours; Nor were the *Jews* the only people that reckon'd thus, for the manner was in use among the *Romans*, as we see by *Persius* his Drunkards, who lay a Bed to digest their Wine — *Quinta dum linea tangitur Umbra*. Nay the *Greeks* followed it also, and had Machines or Clocks (as *Achilles Tatius* tells us) which could (notwith-

A most ready way of finding at any time the *Babilonian* and *Italian* Hour all the world over. Of the *Judaic* way of Computing time.

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* Op. 10. sec. 3. pag. 14.

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standing

standing the forementioned strange inequality of Dayes) measure their Time.

A most ready way to find the Judaick Hour.

But this seemingly odd and exotic account, may very exactly and expeditely be perform'd by our *Globe*; for, if the *Globe-maker* divides each *diurnal Parallel* by distinct specks or pricks into twenty four parts, that is to say, if he divides that part of each *Parallel* above the *Horizon* into 12 equal ones, and that below it into the like number, you have nothing to do but to hold up your *String* against the *Sun*, and if you move it from the *Pole* on its *Noose*, 'till its shade passes over the contrary *Pole*, then upon what prick soever the shade falls, *that* will be the requir'd hour; and in like manner if you know the *Sun's Depression*, draw but your *String* over his then Place, and it will cut the *Parallel* at the true *Judaick time of the Night*.

Why the days of the week being called by the Names of the Planets follow not each other after the order of the Planets
 * To Saturn.
 ♃ Jupiter.
 ♂ Mars.
 ☉ Sol, ♀ Venus.
 ♄ Mercury, ♀ Luna.

These *Unequal Hours* were also called *Planetary* by the *Ancients*, who allowed to each a *Planet* to govern it; so that the first hour (suppose) on *Saturday*, belonging to *Saturn*, if you go on still in the usual *Cœlestial Order*, as 'tis express'd * in the *Margent*, and consequently assign *Jupiter* to the second hour, *Mars* to the third, &c. the 25th (i.e. the first hour of *Sunday*) will happen to the *Sun's Lot*, and the first of *Munday* to the *Moon's*, and so forward: and thus you may see how it came to pass that the dayes of the week succeeded in the present order, and not according to that of the *Planets* in the *Heavens*, that is to say, why *Dies Luna* (or *Munday*) and not *Dies Venus* (or *Fryday*) immediately follows *Sunday*.

The Advantage in reckoning the Italian way.

I shall now end this Discourse, after I have told you, that if we *English-men* think these Computations strange, they that use them, wonder as much at ours; nay, each man pretends some particular Convenience and Advantage by his Method; For first, an *Italian* says, that without breaking ones Brains no body can tell our way when the *Day ends*, so that idle men, who usually hate computing do often couzen themselves, and take false measures in their Affairs, for (continues he) if they chance to get up at 8 of the Clock in *Winter*, they fancy a whole day (even *St. Barnabas's*) before them, when as this Hour or early rising to Him, is 16 of the Clock, which informs him at the very instant, there are but 8 hours to Night.

The Advantage in reckoning the Babylonian way.

The *Caldean* on the other side urges that *Morning*, being the most precious part of the Day, is fittest to be nicely known, and

and tho' his Hour gives him not presently the Distance to the Evening, yet it so alarms him, as to what relates to the *Morning*, that he cannot make the least slip therein, without being at the same moment conscious of his failure.

Lastly, the *Jew* approving both Reasons highly, triumphs in his way; for he no sooner looks (he says) upon his *Dial*, but sees there not only what hours are past, but also what remain, and are yet behind.

But notwithstanding all these shews and pretences of Reasons our *Account* is so far from coming short of any, that in reality it surpasses all; for we not only know exactly what we want every moment of *Noon* (a thing of mighty Concern) but can appoint positive hours all the Year long, for any Employment whether private or publick, whilst these other ways (by reason of the *Suns* inconstancy in *Rising* and *Setting*) have all orderly and set times (as when to *Dine*, when to *Sup*, when to *Rise*, when to go to *Bed*, &c.) still mutable and fleeting.

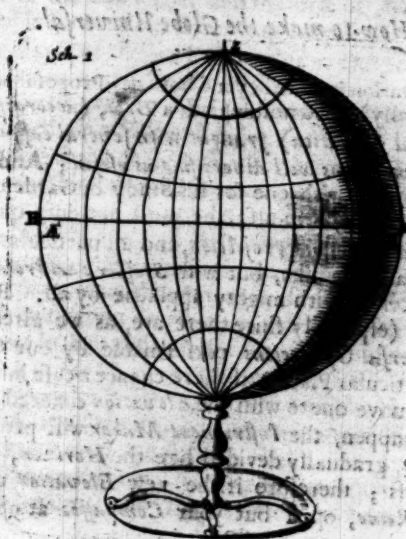
OPERATION XV.

How to make the Globe Universal.

THIS Operation is quite beyond both my Proposal and Design; for I really intend nothing but a *Dial*, (according to a Determin'd Elevation) fraught with several easy and natural Performances, as well divertising as useful; And if a man cannot be content with one for his Study or Garden, unless it may serve for *Jerusalem* also, he must not only quarrel with Mr. *Oughtred's* excellent Projection, and all particular *Analems*, *Quadrants* and the like, but with *Stoffler's Astrolabe*, an Instrument received with mighty applause by all. Besides, 'tis forty to one (especially since there are, as we already see, so many Universal Operations performable by our Globe, tho fixt for a particular Place,) if there chance a case in seven years that would move one to wish the Elevation changed; Yet least this might happen, the Instrument Maker will prepare a thin *Brass Circle*, gradually divided like the *Horizon*, and of the same bigness; therefore if the new Elevation were (suppose) for *Rome*, open but your *Compasses* at 90 Degrees in

any of the great *Circles*, or, take the same distance with your *String* and *Bead*, and having designed by your said *Compass*, or *String* any two *Points* thus distant from *Rome*, clap over your new *Horizon* so, that its divided edge rests on the said two *Points*, or in short, let *Rome* be the *Pole* of the *Brass Circle*, and 'twill cut all the *Equinoctial Parallels*, as if the *Globe* had been made for that *City*, and consequently you will soon have there, the *Suns Rising, Setting, Amplitude, Ascensional Difference, &c.* Moreover the *Circle* being exactly made, will stick of it self, or, at least by the help of any scrap of *Paper* between, so that if at any time you set but the *Plummet-end* of your *String* on *Rome*, you may then hold it down with one *Finger*, and operate as you would do from your own *Zenith*.

But since I am fallen upon this needless affair, and since the *Operation* is in effect the changing of the fixt and standing *Site* of our *Globe*, 'twill be perchance not amiss to inform you (if you are not already well vers't in the *Sphere*) that there are three different and distinct *Positions* of it, which you will better comprehend, if you consider your self in these three *Places*.

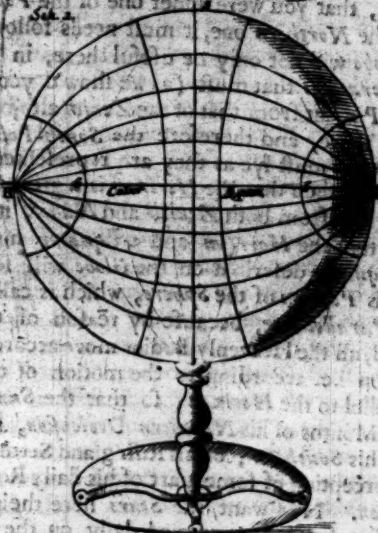


Suppose first, that you were under one of the *Poles*, and for Example sake, the *Northern* one, it must needs follow that that *Pin* on your *Globe* will not only be useful there, in relation to the several *Operations* that must (as we shew'd you) be done from the *Polar Pin*, but from that of the *Zenith* also; because now 'tis the *Zenith* there, and therefore the *South-Pole* being the *Nadir*, all *Circles* must lye as they are represented in *Scheme* the first. Seeing then that the *Horizon* is a great *Circle*, and always 90 Degrees from both *Zenith* and *Nadir*, it will necessarily happen that the *Horizon* and *Aequator* must concur, so that the *Aequator* describ'd on the *Globe* will serve for an *Horizon* in this *Position* of the *Sphere*, which is called by *Geographers* the *Parallel* one, because by reason of the concurrence aforesaid, all the *Heavenly Bodies* move according to their *Diurnal* motion i.e. according to the motion of the *Primum Mobile* parallel to the *Horizon*; so that the *Sun* cannot Set during the six Months of his *Northern Declension*, nor rise during the six of his *Southern*; for his Rising and Setting imply the cutting or intercepting of some part of his daily Road or Track by the *Horizon*. Nor want the *Stars* here their particular *Properties* also; for being carried daily on the *Poles* of the World, and consequently moving parallel to the *Aequator*, all that are above the *Horizon* cannot go under it, nor the others emerge, unless some, by their proper motion after a long series of time, change that Order. Having then in this *Sphere* the *Zenith* and *Horizon*, whatsoever is performable by your own *Zenith* and *Horizon*, may be here (*mutatis mutandis*) perform'd after the same manner.

Leave then but this *Pole*, and every Step of it under any *Meridian* (as suppose the *Solstitial Colure*, or 12 a Clock *Hour Circle*) makes it no longer your *Zenith*, but to decline more and more towards your *Horizon*; so that by that time you get to the *Aequator*, both it and the opposite *Pole* will be 90 Degrees from your *Zenith*, and lie consequently just in the *Horizon*, as appears by the Second *Scheme*, which is called the *Right Sphere*, because the *Horizon* (which is here represented by the *Aequinoctial Colure* or 6 a Clock *Circle*) cuts the

Of the Right Sphere.

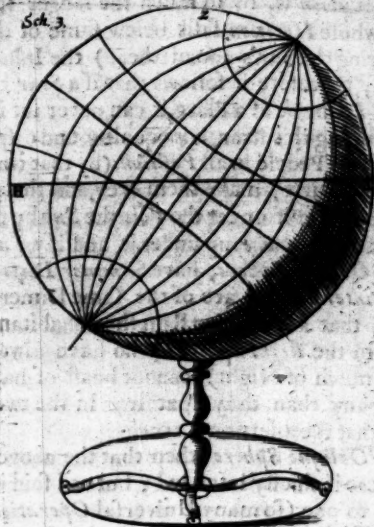
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Proprieties
belonging to
the Right
Sphere.

Op. 17. p. 47.

Equator and all *Parallels* to it at Right Angles, and in half; therefore it appears plainly now, that both the *Sun*, *Stars*, &c. are here to be just 12 hours above & 12 below the *Horizon*. Besides as in a *Barrel* every Concentric Hoop, or Circle whether small or great, turns just about as the *Barrel* does, having all correspondent Points up and down at the same Instant, I say, as it happens thus in an ordinary *Barrel* so it must also happen here; for the *Equator* and its *Parallels* do not a little represent such a Figure; and therefore the *Sun* must be as many Hours in his Journey round the *Tropics* as the *Equator* it self; Nay, any *Star* rising with a Degree of the *Equator* which is its *Right Ascension*, as we hinted in the last Section, must still accompany each other, and having past under every hour Circle together, set at last in the same Order. To conclude, your *String* from the *Zenith* will be as useful as formerly, for your *Read* will as well shew you what you here desire, as at your own Dwelling.



As for the *oblique Sphere* which is the third and last *Position*, and here express'd by the third Scheme, we are in it (you must know) our selves, and so are all other People and Places of the World that are in neither of the two former ones; for take any point not under the *Poles* of the *Equator* for your *Zenith*, and 'twill be impossible to describe an *Horizon* or *Circle* 90 Degrees from it, which cuts not the *Equator* and all its *Parallels* obliquely. 'Tis this *Obliquity* then that gives name to the *Position*, and 'tis this that makes the great inequalities in days and nights, for if the *Horizon* has a greater portion of one *Diurnal Parallel* above it, than of another (as it must needs have by its slanting) 'twill follow, when the *Sun* is in such a *Parallel*, that the Day will be longer, than when the portion was less, and consequently (since more of one *Parallel* is under the *Horizon* than of another) that one Night is shorter than another; and seeing the nearer the *Pole* is to the *Horizon*, the more equally it cuts the said *Parallels*, and the further it is from it, the greater the inequality happens to be, 'tis no wonder that by how much the greater.

Oblique Sphere.

All Position
(taking the
year round)
enjoy an e-
qual share of
the Sun's pre-
sence.

greater the *Elevation* is, by so much the longer the Days are; and when the whole *Horizon* falls below some of the *Parallels*, that then (during the Sun's abode there) the Inhabitants have no night at all; therefore it follows that if a *Star* be nearer the *Pole* than is the *Latitude* of a Place, it can never set in that Place. Yet notwithstanding this strange inequality and disproportion of *Day* and *Night*, all People in all *Positions* (by that time the *Sun* finishes his annual Course) make them even, and thereby enjoy an equal share of both; for if under the *Pole* the *Sun* be six months above the *Horizon*, he is as long under it, and if we and the Rest, that live in the *Oblique Sphere*, have *Summer Days* of a mighty length, our *Winter Nights* are of the same Dimension; therefore it follows, that at the long Run the Inhabitants under the *Equator*, or in the *Right Sphere* (who have always 12 hours of Day and as much of Night) cannot boast of having more of the *Sun's* Company than they that live in the two other, and consequently that the assertion is true.

'Tis in the *Oblique Sphere* then that the above-mentioned *Braken Horizon* is chiefly intended; but as I said in the beginning, 'tis forty to one (so many *Universal Operations* being perform'd by the *Globe* in its set Posture) that in 7 years a man lights on a Question, that could invite him to change it, were it moveable as other *Globes* are; so that having show'd you that (in case of Necessity) it may be in effect altered even without stirring it from its *Pedestal*. I shall proceed.

OPERATION. XVI.

How to take the Elevation of the Pole in any place whatsoever.

Suppose you were in a strange Place, and that your *Globe* being one, that had bin fitted for *London*, you desire to know the present *Elevation*. Expose your *Globe* to the *Sun* on a *Meridian Line* with the *Pin* or *Needle* in the Hole on the *Parallel* of the 10 of *April*, or true day of the Month, and observing at 12 a clock (when the *Sun* comes into the Plain of the *Globe's Meridian*) that the shade of the said *Needle* or *Pin* loses not its felt as it would do were the *Sun* directly opposite to it, for so it had hapn'd at

Lon.

Vid. Op. 3. sec.
1. pag. 8.

London, or in any place in the Latitude of $51^{\circ} 30'$. I say, having thus expos'd your *Globe*, and observing this, move your *Pin* or *Needle* from *Hole* to *Hole*, or from one Degree of the *Meridian* to the other, 'till it's shade be wholly lost, and finding the said *Needle* or *Pin* on the *Parallel* (suppose) of *June 11th.* which is about $11. 30'$ higher then it's proper place (to wit the *Parallel* of the *10th* of *April*) you may conclude that your present *Elevation* is 63 degrees, i.e. $11. 30'$ higher than the *Globe's*; whereas had, you bin oblig'd to move your *Needle* or *Pin* so many Degrees lower than the *10th* of *April*, your *Elevation* had bin but 40 .

The *Demonstration* is obvious, for since the Earth is round; as nothing perchance proves it better, than the Experience we have, that as so many miles (suppose 60) elevates or depresses the *Pole* one Degree, so just 60 Miles more elevates or depresses it another: I say, since the World is round, and that the Degrees of the *Globe* answer to its Degrees, it must follow that the difference between the *Pins* situation now on the *Globe* and where it would have stood on it at *London* is the true difference of the two *Elevations*. The Demonstration.
How the Earth is proved Round.

OPERATION XVII.

How to know in what Elevation the Sun Rises or Sets, an hour, or any other space of time, earlier or later than he do's in the Globes Elevation.

IF the Sun rising at *London* on the *10th.* of *April* about 5 , and setting about 7 , you would know in what *Elevation* or *Latitude* he then rises, (for examples sake,) at 4 and sets at 8 , take the distance of 90 Degrees with your *Siring* or *Compass* in any great Circle, and placing one end of your *Siring* or one foot of your *Compass*, where the *Parallel* of the day intersects with the Hour-Circle of either 4 in the morning, or 8 at night, observe where, or at what point the other end of your said *Siring* or other foot of your said *Compass* touches in the *Meridian*, or 12 a Clock Circle of the *Globe*, and you will find it to be at, or about 8 Degrees and 30 Minutes, beyond the *Zenith* towards the *North Pole*, so that the *Elevation* required is greater than your

your own by those 8 Degrees and 30 minutes, that is to say the *Elevation* is that of 60 or thereabout; whereas had your *String* or *Compasses* touch't 8. & 30'. on the other side of your *Zenith*, the required *Elevation* would have been less than your own so many Degrees, i. e. it would have been that of 43 Degrees or thereabout.

*The Demon-
stration.*

This appears true by placing your *Brazen Horizon*, or by describing an imaginary one over the two points made by the Intersection of the *Parallel of the Day*, and *Hour-Circles* of 4 in the morning and 8 in the evening; for in the *Elevation* belonging to such an *Horizon*, 'tis evident that the *Sun* rises at 4 and sets at 8. Now the *Pole* of every Circle being 90 Degrees from it, and the *Point* in the *Meridian* being 90 Degrees from the aforementioned Intersection, it follows that the said *Point* in the *Meridian* is the *Zenith* or *Pole* of this new *Horizon*, and consequently by being distant from the *Aequator* 60 Degrees, that so many Degrees is the *Latitude* or *Elevation* required.

The END of the second Section.

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SECT. III.

Of the Moon.

HAVING now finish'd with the *Sun*, we'll make a step, if you please, to the *Moon*, and show you how to resolve all the useful ordinary Questions concerning her, whether we see her by Night or by Day; for 'tis equal to us whether she shines our right, and consequently casts a shade, or appears only faint and wan, by reason of thin Clouds, or by the excess of Light during the *Sun's* abode above the *Horizon*. Let us then begin with her *Altitudinar* and *Azimuth*, as being the Basis and Foundation of all Operations here relating to her; nor can there be the least difficulty in any of them, unless perchance in the 7th.

since they have so great a Correspondence and affinity with those already handled in the former Sections.

OPERATION I.

To find the Moon's Almucantar or Height.

THIS is to be perform'd as well when the cast's a shade, as when the cast's none, by the two first ways of finding the *Sun's Almucantar*, and therefore consult the * *second Operation* * pag. 5. in the first Section.

OPERATION II.

To find the Moon's Azimuth.

THIS is also to be found by the two first ways of finding the *Sun's Azimuth*, treated of in the * *5th. Operation* * pag. 10. of the first Section.

OPERATION III.

To find her true place on the Globe.

IF the cast's no shade, her place is to be found by her *Almucantar* and *Azimuth*, as we hinted in the * *6th. Ops.* * pag. 11: *ration* of the first Section, since she must ever be where these two Circles intersect; But if she shines out clear, you have nothing to do (having plac'd your *Globe* on a *Meridian Line*) but to see what hour the shade of the enlightn'd *Pole*, or that of your *String* (passing over both *Poles*) mark's; for this giving you her hour-Circle (which we'll call the *Lunar hour* hereafter) her height or *Almucantar* must needs tell you in what part of the said Circle she resides. This *Operation* is to be well understood and readily perform'd, seeing

OPERATION. VI.

To find the Moon's Bearing according to the Points of the
Compass.

THIS is to be perform'd after the way of finding the
Sun's Bearing, in the 7th. Operation of the first Section;
for if you draw your String from the Zenith over the Moons
present Place, the said String cuts (by our Example) the Ho-
rizon at S. W. and some few Degrees towards the South for her
then Bearing. * p. 12.

OPERATION. VII.

To know what a clock it is by the Moon.

THere is no Operation treated of so intricate as this, and
therefore if the Reader (who would have his Curiosity
satisfy'd) has not Patience enough to descend to a little niceness,
he had better fall upon another Subject; but tho' we may be
somewhat long at first, in laying down and explicating all Parti-
culars, yet at the end we will contract the whole into half a do-
zen Lines, and thereby make the Operation very expedit, and
easy; I say, there is no Operation so intricate as this; for, the
Moon by reason of her different Place in her Epicycle, is so in-
constant in her daily Elongation from the Sun, that sometimes
she spends from (v.g.) her Conjunction to her first Quar-
ter above 8 days, tho' at another time a great deal less than 7
will serve the turn; and to this variety and skittishness is the
space also between any of her other changes liable. If then her
distance from the Sun be so uncertain, and yet is the thing that
must be known before her Place, or shade on the Globe can give
us the hour we seek; how strangely fallible is the usual way (as
well in some Authors of Note, as in ordinary Almanacks) of
finding it, to wit, the adding of as many 48 minutes to the hour
she shows on a Dial, as she is days old; for the Tables, made
in pursuance of this Rule, suppose her always on the 15th of her

Age to be at *Full*, which may happen (as I now mention'd) not only much sooner, but also much later, so that most commonly her true Age and the said *Tables* are at variance; nay, when they agree, there can be no Reliance on them, seeing that if (*v. g.*) at 6 they show tolerably what a clock it is, yet by 12 there may happen an Error of near a Quarter, by reason that she is every moment at a new distance from the *Sun*, and at one also which presently becomes very sensible. Thus therefore we see that there must be Exceptions and Restrictions in any one Rule that appertains to this business; nor is it to be perform'd by an Instrument in a trice, as the *Operations* commonly are belonging to the *Stars*, that have a Regular motion, or to the *Sun*, whose Extravagance is not soon perceptible; I say, thus we see that there must be here Exceptions and Restrictions, and in truth nothing but a down-right *Astronomical Calculation* can really perform it; yet since such a critical Exactness in the hour is never necessary in our ordinary affairs, I shall propose this method, which will at least come always very near the Mark.

How you are
to operate:

When you desire to know what a clock it is by the *Moon*, take an *Almanac* (for if you would only have her true Age, you must recur to one, or to something analogical) and reckon therein how many dayes there are in the present *Quarter* from one *Change* to the other, *i. e.* from *New Moon* to her *First Quarter*, or from her *first Quarter* to her *Full*, and so on; for I call any of these four *Aspects* a *Cardinal Point*, or *Change*, and the whole time between one *Change* and the other a *Quarter*; I say, Reckon how many Days there are, in the then *Quarter*, and you will find either 6 $\frac{1}{2}$, or 7, or 7 $\frac{1}{2}$, or 8, so that if the number be 6 $\frac{1}{2}$, her *Elongation* from the *Sun*, is 3 Minutes and $\frac{1}{2}$ per *Diem*, if 7 Days 51 $\frac{1}{2}$, if 7 days and half, 48, and lastly if 8 Days, 48. I mean not nevertheless that from *Change* to *Change* there may not sometimes happen 6 days and 16 hours or 6 Days and 20 hours, and several such Fractions and Deviations from the Positive Terms prefixt by me: but since the forementioned whole and half dayes will bring us to a knowledge exact enough of the hour sought for, we call 6 days and 16 hours, 6 dayes and a $\frac{1}{2}$, only, as coming neerer to it than 7 whole ones; In like manner, we call 6, and 20 hours 7 days, and deal in this Proportion with all other number of days

and hours which the *Ephemerides* or Almanack give us concerning the length of the requir'd *Quarter*.

And here you may be pleas'd to remember also, that it would not be amiss, in case you exceed much any of the fore-said terms, to add or cast away sometimes a minute or a little more, as you shall see Cause; For if (v.g.) you find the *Moon* to be six days and 17 hours in her journey (which according to our former Directions is to be reputed only six days and $\frac{1}{2}$; and consequently the *Elongation* 55' $\frac{1}{2}$; you may then cast away 1', because of this great excess above the half day; and if you should find her at another time to be 7 days and twenty houres, i.e. eight days, you may add for the want of the four hours a minute, and make her daily *Elongation*, 46 instead of the forementioned 45; but here you may do as you you please, for the error will not be considerable.

A Memorandum.

These Particulars being premis'd, let us come to an Example. *An Example.* And Suppose then that on the fifth of *January*, finding the *Moons* shadow to marke two in the afternoon on your *Globe* for the *Lunar hour*, you should desire to know the true, or *Solar hour*.

First your *Almanac* can tell you not only that the *Moons* last *Cardinal Point*, was (v.g.) her *Conjunction*, but how many Days and Hours she spends in going from it to the next *Cardinal Point*; for finding there her said *Conjunction* to be on the first day (suppose) at seven at night, and that she comes to her first *Quarter* on the ninth day, near the same hour, you may presently conclude she is 8 whole Days in this Voyage, and consequently that her Diurnal *Elongation* from the *Sun* will be 45 minutes. Now because the said fifth day is the 4th of her Journey, if you multiply 45 by 4, or look in the *Tables* (which we shall presently show you) belonging to her 8 Days Journey, you'll have three hours for the time that she is behind the *Sun*, so that the *Solar* or true hour must be five at night, wanting four minutes; for you are always carefully to subtract two minutes for every hour the *Moon* wants of compleating her whole Days march, which in the present case happens, not before seven at night; whereas you must have added them, had the *Solar hour* bin nine at night, because then her *Elongation* from the *Sun* would have been 4 minutes more than the aforesaid three hours.

'Tis

Two Memorandum.

'Tis in this manner you are to operate in all cases; but before we proceed, take these two *Memorandums* with you. First, That by the *Moon's* completing a day's journey, I mean 24 hours after the time (let it happen by night or by day) of her entering into her last *Cardinal Point*; as for Example, If she comes to her *Conjunction*, or any other *Cardinal Point*, at 7 in the Evening on (v. g.) *Monday*, then at 7 in the Evening on *Tuesday* she has completed one day's journey, and at the same hour on *Wednesday* two Days, and so on till she comes to her next *Cardinal Point*. The second *Memorandum* is, That whereas (in the late Example) her *Elongation* from the *Sun* was three hours (because you sought what a Clock it was on her fourth days journey from her *Conjunction* to her *First Quarter*, at the *Elongation* of 45 minutes *per diem*.) Now had she been thus advanced in her Course from her *First Quarter* to her *Full*, or from her last *Quarter* to her *Conjunction*, you must have added 6 hours to the said 3 hours, so that then the true hour would (instead of 5 at night) have been 11; and this is to be a general Rule.

The reason or demonstration of the Operation.

Thus much then for the way of finding what a Clock it is at any time by the *Moon*, and now let us make good what we have said. First we see, that to know the Hour by the *Moon*, is to know the difference between the *Lunar* and *Solar hour*, i. e. between the hour Circle she is in, and that in which the *Sun* happens (at the same time) to be; or, in other Terms between the hour she marks on the *Globe* by her shade, and that which the *Sun* would mark did he then appear; Now seeing that in her Course from one *Cardinal Point* to the other, she seldom spends the same number of days and half days, it follows (as we hinted in the beginning) that no certain number of minutes, can be allowed for her daily *Elongation*; But if we divide 6 hours, or 360 minutes (i. e. her total *Elongation* from one *Cardinal Point* to another) by the Days and half days she spends in the journey, the *Quotient* must be her *Diurnal Elongation* (at least to sense) during that *Quarter*. Now since the *Diurnal Elongation* is, as you see most commonly above three quarters, and sometimes almost an hour, the *Horary* one must be (as I said) considerable, seeing in the space of every 7 hours it may amount to above a quarter more; therefore this inconvenience we obviate by allowing two minutes for each hour after

ter her compleat days journey, and subtracting them from what she wants of it.

Here I confess there may be an Error, but it is hardly worth the mentioning; for when she is either 8 days, or 7, in her journey from one *Cardinal Point* to another; i.e. when her *Diurnal Elongation* is either 45', or 51' and $\frac{1}{2}$, the difference from 48 minutes a day (or 2 minutes an hour) cannot be but $\frac{3}{4}$ ' and $\frac{1}{2}$ in a whole day: nay, when her *Elongation* is 55' and $\frac{1}{2}$ i.e. when she spends 6 days and $\frac{1}{2}$ in her voyage, the difference is but 7' and $\frac{1}{2}$ from the aforesaid 48 minutes; nor can this happen till the end of every compleat days journey, and consequently is not perceivable for the greatest part of it. But since we here see where and how any error may arise, it is easily remedied by an Allowance, if any man thinks it worth the while to be so exact.

A memorandum.

As for the Reason why, if she be in her Course from her *first Quarter* to her *Full*, or from her *last Quarter* to her *Conjunction*, we must add always six hours to the *Elongation*, which our Calculation or the *Tables* give, it is, because the said *Elongation* is only the precise time of her Departure from her *last Cardinal Point*, whereas if she be past her *first Quarter* in her Journey towards her *Full*, she is so much and six hours more, i.e. so much and the six hours, which happen from her *Conjunction* to her *first Quarter*. Now in rigor we should add twelve hours to the *Elongation* we find, when she is gone from her *Full*, towards her *last Quarter*, but seeing she is in the *Plane* of the same *Hour-Circle* or very near it, both at *Full* and in *Conjunction*, therefore the bare adding the said simple *Elongation* will serve as well in one case as in the other; for if, the *Full Moon* (at suppose 2 of the Clock at night) casts really her Shadow on the *Hour-Circle* of 2 in the Afternoon, yet there's no need of hints (the thing being so plain), to prevent your mistaking Day for Night. The like also is to be said of the *last Quarter*, whose *Elongation* should be in truth eighteen hours, but the additional six hours (as we allow her after her *first Quarter*) are sufficient, since no man can be so ignorant as to take the Morning for the Evening, notwithstanding the *Lunar hour* should be upon a *Morning Hour-Circle*. To facilitate then this Operation (least what we have already said has proved tedious), we will conclude (as I promis'd) with a short Recapitulation.

Why 6 hours must be added sometime to the Tables.

pitulation or Abstract, as also with the *Tables of her daily Elongation*, let the time be what it will (as we said) that she spends in her Journey from one *Cardinal point* to the other.

The Abstract of the Operation in finding the true Hour by the Moon according to the late Example.

AS for the *Almanac*, there are three things (we see) it informs us of, viz. 1. The Hour when the *Moon* came to her last *Cardinal Point*. 2. How many days she is going from the said *Point* to the next; and, 3. In which *Days Journey* she is at present. Knowing then, according to the late Example that the *Moon* will be eight days running throu' her *Quarter*, and that she is in the fourth *Days Voyage*, 'twill follow that the fourth day in the Table (whose title is eight dayes) will tell you that her present *Elongation* from the *Sun* is three hours; so that the *Lunar-hour* being two in the afternoon, the true hour must be just five at night, only twice two Minutes are to be abated, because she lacks 2 hours from compleating her said fourth days voyage; for your *Almanack* (according to our supposition) informing you that it was seven at night when she set out from her last *Cardinal Point*, it must be still seven at night before she compleat's any whole day's Journey during that *Quarter*.

This then is the summ of the whole Business, nor need you trouble your self with any other Reflexion unless it be to add six hours (as I already said) to the *Elongation*, in case she be going from her first *Quarter* to her *Full*, or from her *Last* to her *Conjunction*. And to conclude take notice, that the hour (if you see the *Moon*,) may be as well found by day as by night, for her Place on the *Globe* (which the third * *Operation* shew's how to find) is always the true *Lunar hour*.

* p. 49:

Tables

Tables of the Diurnal Elongation of the Moon from the Sun, whether she goes in 6, 7, 7½, or 8 days, from one Cardinal Point to the other.

| | | | |
|----------------------------------|--------------------------|---------------------|-------------|
| Days from her Cardinal Point. | 6. $\frac{1}{2}$ Days | | Elongation. |
| | Card. Point. | | |
| | 0.----- | 0.0. | |
| | 1.----- | 0.55. $\frac{1}{2}$ | |
| | 2.----- | 1.51. | |
| | 3.----- | 2.46. $\frac{1}{2}$ | |
| | 4.----- | 3.42. | |
| | 5.----- | 4.37. $\frac{1}{2}$ | |
| | 6.----- | 5.33. | |
| | 6. $\frac{1}{2}$ ----- | 6. 0. | |
| Hor. min. | | | |

| | | |
|--|--------------------|---------------------|
| <i>Days from her Cardinal Point.</i> | | + |
| | | 7. |
| | | <i>Days.</i> |
| | | <i>Card. Point.</i> |
| | 0. --- | 00. |
| | 1. --- | 0 51. $\frac{1}{2}$ |
| | 2. --- | 1 43. |
| | 3. --- | 2 34. $\frac{1}{2}$ |
| | 4. --- | 3 26. |
| | 5. --- | 4 17. $\frac{1}{2}$ |
| 6. --- | 5 9. | |
| 7. --- | 6 0. | |
| | <i>Hor. min.</i> | |
| | <i>Elongation.</i> | |

| | | | |
|--|------------------|--------------------------------|--------------------|
| <i>Days from her Cardinal Point.</i> | | $7\frac{1}{2}$ <i>Days.</i> | |
| | | <i>Card. Points.</i> | |
| | 0. | 0.0. | <i>Elongation.</i> |
| | 1. | 0.48. | |
| | 2. | 1.36. | |
| | 3. | 2.24. | |
| | 4. | 3.12. | |
| | 5. | 4.0. | |
| | 6. | 4.48. | |
| | 7. | 5.36. | |
| 7 $\frac{1}{2}$. | 6.0. | | |
| | <i>Hor. min.</i> | | |

| | | | | |
|--|-------|--------------------------------------|-------|--------------------|
| <i>Days from her Cardinal Point.</i> | | $\begin{matrix} + \\ 8 \end{matrix}$ | | <i>Elongation.</i> |
| | | <i>Days.</i> | | |
| | | <i>Card. Point.</i> | | |
| | 0. | ----- | 0.0. | |
| | 1. | ----- | 0.45. | |
| | 2. | ----- | 1.30. | |
| | 3. | ----- | 2.15. | |
| | 4. | ----- | 3.0. | |
| | 5. | ----- | 3.45. | |
| | 6. | ----- | 4.30. | |
| 7. | ----- | 5.15. | | |
| 8. | ----- | 6.0. | | |
| | | <i>Hor. min.</i> | | |

These Tables are to be on the Globe in the most vacant and free parts of it.

OPERATION VIII.

To know how many hours the Moon has been up, and how many she lacks of her setting, as also how long she is to be that day above the Horizon.

THis is done by numbring the Hours or Hour Circles between the *Moons* place in her *Parallel* on the *Globe* and the intersections of her said *Parallel* with the *Horizon*; for having found that her *Parallel* cuts the *Horizon* in the *East* at the five a clock hour circle, and in the *West* at that of seven, and seeing that her present *Place* is (e.g.) at that of two in the afternoon, you may conclude that she has bin up nine hours wanting eighteen minutes, that is, eight hours and forty two minutes, and will set within 5 hours wanting ten minutes, or four hours and fifty minutes; for the *Moon* goes from *East* to *West* (by the Motion of the *Primum Mobile* or *Motum Raptum*) two Minutes (as we suppose) every hour (take one time with the other) slower than the *Sun*; which happens by her being too quick for the *Sun* in her own Motion, that is to say, in the Motion of the *Center* of her *Epicicle*, which carries her from *West* to *East*; therefore the *Moon* according to the present Example or Supposition will be above the *Horizon* fourteen Hours wanting twenty eight Minutes, *i.e.* about thirteen hours and a half.

OPERATION IX.

To find at what a clock the Moon rises and sets.

BY the last Operation you are inform'd of the hours from her present station to her *Rising* and *Setting*, which hapning in the Example to be about eight hours and forty two Minutes for the one, and four hours, and fifty minutes for the other, it must follow, (having found the true hour to be within four minutes of five at Night) that she rose about eight and fourteen minutes in the Morning, and will set at nine and forty six minutes at Night.

OPERATION X.

To find how long the Moon shines every night.

HAVING found by the precedent Operation, that the Moon sets at 9 and 46 minutes at night, and that the Sun (by the 12th. of the first * Section) sets the same day, (suppose the 8th. of February) at 5 in the Evening, 'twill follow that the shines four hours and 46 minutes. * p. 16.

OPERATION XI.

To find when the Moon comes to South, and consequently when tis high water at London Bridge.

HAVING found by the * third Operation the Moons place to be in the 2 a Clock Circle, you thereby see that she is past the South 2 hours and 4. minutes, Now since it is always High-water at the Bridge three hours after her coming to South, and since the Solar or true hour is (according to our Example) 5 at Night, it follows 'twas High-water at 4 minutes before 6. and consequently 'twill be high water again at the same hour next morning, and 24 minutes; for from one Tide to the other there are always about 12 hours and 24 minutes. * pag. 49.

OPERATION XII.

To know in any Eclips of the Moon, what Countries see it wholly, what in part, and what not at all.

PLACE your Globe on a Meridian Line, or otherwise Compose it, and when you perceive the Moon to begin to enter into the shade of the Earth, consider (as you do when you seek by the * Suns Rays where 'tis day and night) what part of the Globe is illuminated, and what not; for, since she appears to all Countries that lie in the Light, and is hid from those in the

Shade, you have not only a view of what people see her in her then condition, but may (till her total immersion) perceive by her illumination how the Countries, that lye in or near the *Fallowing Shade of Extuberancy*, loose every moment the sight of her, and consequently, *who they are that took leave of her in the beginning of her Eclipse, who when she came to half of it, and who when wholly obscur'd*, with infinite more Reflections of this nature. On the other side you may find, how some that lay in the *preceding shade of Extuberancy* saw nothing of her at first, but now begin to discover her in her Angony; and if you draw on the *Globe* a little Circle with Chalk or the like, in the *Confin*es of the obscurity and light, just as she begins to be wholly in the shadow, you will discern (by the space between the said Chalk and the new shade of extuberancy at her Emersion) *what people never saw her, tho she were above their Horizon*. Infinite are the Reflexions (as I said) of this nature, but these are sufficient to show you how to make more your self; so that now I will end after I have remembred you, that the *Sun* being by his *Opposition* in the same hour Circle with the *Moon*, especially in all *Central Eclipses*, nay he is so (as to sense) for some time both before and after such *Eclipses*; I say, the *Sun* being so, you may therefore not only (by the bare shade of the *String*, or that of the *illuminated Pole*) know what a Clock it is from time to time in the *Polar Circles*, but in the *Equator* also, by the *shade of Extuberancy*, which performs the observations above mentioned; and thus by the very same shade you find not only *what People see the Eclipse, either in whole or in part*, (as we now told you) but *at what hour it appears to each of them, and how long*; as also the *Duration of her Decrease and Encrease in light*, together with the time of her total Obscurity; moreover, *this very shade gives you her Height and Azimuth all along, as you may see in the * Operations that concern them.*

* Vid. Op. 1. §
2. pag. 49.

OPE

OPERATION XIII.

To represent the several Phases or Shapes of the Moon by the Globe.

THIS is rather a *Speculation* than an *Operation*, Nor should I have mentioned it, were it not that several (who know something in *Mathematics*) cannot comprehend the Cause of the *Moon's* continual *Metamorphosis* or Change, that is to say, why she should be now more, now less illuminated, and that also in so different a shape and manner. To comprehend therefore this, Expose your *Globe* (elevated on a Stand or a Table as high as your Eye) to the *Sun* or *Moon*, and place your self so before it as to see the whole illuminated half; for (as to sense) the illuminated and shady parts of all Spheres are (as we formerly mentioned) equal. Having then a while consider'd this great Circle made by the Limb or Extremity of the illumination, remove your Station a little on the one side (as for Example towards the righthand) and you will find the illuminated part to appear *Gibbous* or *Oval*, I mean not so broad as long, because so much of it is hid from you, as you can now discover of obscurity. From hence go yet farther side-wise, and the visible part of the *Globe* will be *Dicotomous*, or *party per pale*, that is to say the light and shade will become equal.

After this make another Proportionable step, and all that is illuminated will appear *Horned* or *Lunular*, and the obscure part *Gibbous*; But if you remove to the point opposite to your first Station, you will see nothing besides a dark and shadow'd Hemisphere; whereas should you proceed further in the same Order; you would perceive Light on the other side, first *Lunular*, then *Dicotomous*, next *Gibbous*, and lastly totally predominant.

Now as the *Globe* is always half illuminated, whether we see little or much of the illumination, so it happens with the *Moon*, who being in *Conjunction* appears all dark to us, because her illuminated half is towards the *Sun*, and opposite to us, but as soon as she gets from him, and consequently is no longer in the same Plane with him and our Eye, we must needs have.

have a view of some part of the Illumination, seeing she can only appear wholly obscure when she is thus before the *Sun*. The said Illumination also (since she is Spherical) must seem as on the *Globe* the more *Horned* the less it is, and then blunter and blunter according to her Encrease or *Elongation*, till at last she becomes *Dicotomous*, afterwards *Gibbous*, and lastly *Full*; for by being at her greatest distance from the *Sun*, or in Opposition with him (which causes our Eye to be in the middle or between them) 'tis impossible she should appear otherwise than all *Light*: And here you may be pleased to take notice, that if you compass your *Globe* with a *String* or *Thred* that passes thro' the *Zenith* and *Nadir*, and let one half of the describ'd Circle represent the Illumination and the other the Obscurity, you may perform this *Operation* at any time, whether the aforesaid *Luminaries* shine or no.

A Corollary.

How easy therefore is it to conceive the whole Mystery of the *Moon*s four principal *Changes*, and what men mean by them. For first we see that as she is call'd *New* by an *Astronomer* from her being with the *Sun*, (i.e. as fully between our Eye and the *Sun*, as her then Course permits) so no sooner has he found by their several motions that she is gotten 90 Degrees or six hours from the *Sun*, but he says she is in her *first Quarter*; and when they are asunder 180 Degrees or 12 Hours (to wit as far as ever they can be) that she is *Full*; and lastly, as soon as they are distant 270 Degrees or 18 hours on the same side, and 90 Degrees or six hours on the other, that she is in her *last Quarter*; so that at their next meeting she becomes *New* again.

OPERATION XIV.

How to find how long the *Moon* wants of any *Change*, or *Cardinal Point*, and consequently how old she is.

I Propose not this *Operation* as a thing exact, but seeing it is a *Corollary* of the former, I thought fit to mix it; therefore pray take it for better, for worse, and make of it what you can: To resolve then these Questions by the *Globe*, you are to expose it as before to the *Moon* when she shines, and move about it till you can there just describe her shape; and by the way you will come

come nearer the mark, if you only consider the *Lunular* or lesser Portion, whether it happen to be the obscure or the illuminated part of her whole *Discus* or *Orbe*; I say, describe her Shape on the *Globe*, as neer as you can, and observe how many Degrees the breadth of the *Horn'd* or *Lunular* Portion will be in any great Circle, that crosses it in the middle at Right Angles, and that will give you *rather qualiter* what you seek for, as appears more clearly by the ensuing Example.

Having observ'd, suppose the illuminated Portion of the Moon to be *Lunular*, expose your *Globe*, and move about it till you perceive on it an illuminated *Lunula* proportionable to the Real one, then finding its measure by some great Circle that crosses it at right Angles, to be 40 Degrees, these consequences will follow. First if the *Moon* be in her *Encrease*, she is past being *New* 40 Degrees, i.e. three days and about seven hours, seeing her hourly *Elongation* from the *Sun* (is one time with another) about half a Degree and half a minute; but if she be in her *Decrease*, she wants so many days and hours from being again *New*. In the next Place it will happen that the obscure part of the *Globe* is 140 Degrees broad; for (both parts or portions making up the apparent *Hemisphere*) the said obscure'd Part becomes the supplement of the former 40 Degrees; so that 140 amounting to about 279 hours, or 11 days and 15 hours, you may conclude that if she be *Encreasing*, she wants so much of being *Full*, as also that she is 50 Degrees or almost 100 hours (i.e. four Days and almost four hours) past her first *Quarter*; whereas if she be *Decreasing*, she will want eleven Days and fifteen hours from her next *Conjunction*, and be four days and almost 4 hours beyond her last *Quarter*.

As for knowing the *Moons* state in relation to her *Waxing* and *Waning*, you need only observe on what side of her *Discus* her illuminated Part stands; for if it be on the *West-side* of it, she is in a *Waxing* Condition, if on the *East-side* in a *Waning* or *Declining* one: And here also remember that as to the measuring the aforesaid Portions of the *Moons Discus*, represented on your *Globe*, you may do it by the *Horizon*, if she illuminates not much beyond the *Zenith*, or by the *Equator*, when the illumination reaches to the *Pole* or neer it, or by the *Ecliptic* when it extends it self a good way further; for the said Portion of the *Moons Discus* is measur'd at first sight by that great

great Circle which lies equally distant from each *Horn* of the *Lunula* on the *Globe*, i.e. by that great Circle which crosses it (as we said) in the middle at Right Angles; and when no great Circle does so, you had best measure it exactly with your *Compass*, seeing that on the knowledge of its breadth, the Resolution of all the former Questions depend. Many things of great use may be drawn from knowing the true proportion of the illuminated and obscure parts of the *Moon's Orb*, but this I leave to them that have exacter Instruments than the *Globe*, and more time to make Deductions.

This END of the Third Section.

SECT. IV.

Shewing the Proportion between Perpendiculars and their Shades.

SBeing there is the same proportion between all *Shades* and their *Perpendiculars*, at least to sense, and seeing the several *Almucantars* of the two great Luminaries are the chief Cause of the lengthning or shortning of them, I have here adjoin'd a few by *Operations* even in *Altimetry* it self, as belonging naturally to our *Globe*, since it not only shows us several ways of finding from time to time the said *Almucantars*, but gives us also at the same instant without trouble (as appears by the ensuing *Operations*) the above-mentioned *Proportion*, and consequently the height of all things *Perpendicular* to the *Horizon*.

O P E

OPERATION I.

How to find the Proportion between the Perpendicular and its Shade.

Consider the Northern or back part of the Globes Meridian, which we will call hereafter the *Quadrant of Proportion*, and which is not only devided like the Southern or fore-part into Degrees, but markt also (in relation to the affair in hand,) with several Figures, of which that next the Zenith is 17, and the remotest 188. And by the way you must take notice, that when you see a Cross behind any Figure, it signifies half an Integer more, so that 17 + is 17 Degrees and a half, 26 + is 26 and a half, &c. When you would therefore Operate, Turn the Southern or fore-part of the Meridian towards the Sun, 'till they be both in the same Plane, i. e. 'till the shade of the Pin in the Zenith falls directly upon the *Quadrant of Proportion*, and what Figure soever, (suppose 25) the shade of Exuberancy cuts, that will be the then Proportion between Perpendiculars and their Shades; for here you may take notice, that we ever suppose the Shade to be 100. Nay, if finding (by any of the * former ways) the Sun's height to be (suppose) 14 Degrees, * Sect. I. Op. 2. p. 5. you rectify your Bead to 76 Degrees, or the Complement of it, you need only clap back your String, that is to say, draw it from the Zenith, over the Devisions of the afore-mention'd *Quadrant*, and then the Figures under the Bead (to wit 25) will shew you the required Proportion; In short, take but the Sun's Height (any how) and reckon from the Zenith as many Degrees on your said *Quadrant of Proportion*, and the Figures at the end of your Account will give the Proportion sought for. Now if the Shade of Exuberancy, or the Bead marks not even Degrees for the Sun's Height, but (for Examples sake) 13.30, and consequently falls between the Figures of 23 and 25 in the *Quadrant of Proportion*, you had best (to avoid all Calculation and Allowance) expect a Moment longer, for then the Sun's Height being even, and without Fraction, you may operate as before.

OPERATION II.

How to find the height of a Tower by the Globe.

THIS Operation appears at first Sight to be a *Corollary* of the former, for finding, as I shew'd you, that the *Shade of Extremity* falls in the *Quadrant of Proportion*, on the number (v.g.) 25, and that the said number represents a *Perpendicular*, do but measure the *shade* of any Tower and you will soon have its *height*, seeing that as 100 is to 25 (i.e. as 100 is to the number found on the said *Quadrant*) so is the *Shade* of the Tower, (which being measur'd wee'l suppose 80 yards long) to a fourth number, viz. to 20 the *required height*.

OPERATION III.

How by the help of your Globe to measure any Tower or height, and yet not to seem to use any Instruments in the Operation.

THIS Operation may perchance a little surprize some, and yet it differs not in reality from the former; that showing you how to measure a *height* by your *Globe* upon the place, and this how to do it privately. To perform then the Operation, you must choose (when you are alone) any of the aforesaid Numbers, on the *Quadrant of Proportion*, as suppose 25, and seeing that belongs to the 14th. Degree from the *Zenith*, rectify your *Bead* to the *Complement*, i.e. to the 76th from the *Zenith* in the said *Quadrant*; this being done move your *String* hanging on the *Zenith's Pin*, till your *Bead* touches the *Parallel of the Day*, which we now suppose to be the tenth of May, and the *Hour-Circle*, that meets with it there (to wit that of six in the morning, or six in the afternoon) tells you that at those hours, on that day of the Month, the *perpendicular* will be the fourth part of the *Shade*, i.e. as twenty five to an hundred, so that having discours'd with some body of the possibility

ty of measuring *heights* without an Instrument, repair with him to any convenient place, about the foresaid times of the day, and when you find by your *Watch* that 'tis exactly six, do but measure the *Shade* and you will have the required height. And by the way take notice, that as it is in your power to choose what proportion you please, and the more odd and exotic it happens (if you can quickly reduce it) the better it is, for then People will not perchance so soon comprehend the *Operation*; I say, as you can choose your *Proportion*, so you may choose the *Hour* also, for if your *Bead* be rectify'd to the chosen *Proportion*, according to the foregoing Example and Instructions, and brought to the hour pitcht upon (suppose 3 in the afternoon) the *Parallel*, (to wit, that of the fifth of *February*), which meets with the the said *Bead* and *Hour-Circle*, tells you that then the *Proportion* will thus happen; nay, you may choose what day and hour you please, if you will be content with the casual *Proportion* or number which the *Bead*, when rectify'd (as we mentioned) falls upon.

OPERATION IV.

How to find the Hour by your Stick.

YOUR *Stick* being divided into ten equal parts, and each part by Pricks into as many equal Subdivisions, you must operate thus. Rectify your *Bead* (on the tenth v. g. of *April*) to the *Sun's Meridian Altitude*, and if you then move your *String* on the *Pin* of the *Zenith*, to the *Quadrant of Proportion*, the *Bead* will lye (for Example) on 87, so that having writ this on Paper with the figures of 12 above it, draw your *String* from the *Zenith* over the next *Hour-Circle* on which hand you please, I mean either over that of 11. or 1. and where your *String* cuts it on the said *Parallel* of the day, there place your *Bead*, and 'twill lye (v. g.) on 93 in the said *Quadrant of Proportion*; noting then 93 in your paper under the hours of 11. and 1. proceed then in this manner from *Hour-Circle* to *Hour-Circle*, 'till you come to 6, for after the *Sun* is within an hour of his *Rising* or *Setting*, you may easily guess what time of Day 'tis; besides shadows are then so long that they are troublesome to measure;

I say proceed in this manner to 6, and a Table like that in the

| | | | | | |
|-------|-----|------|------|------|------|
| * 12. | 1. | 2. | 3. | 4. | 6. |
| -- | -- | 10. | 9. | 8. | 7. |
| -- | -- | -- | -- | -- | -- |
| 87. | 93. | 110. | 140. | 200. | 300. |

* Margin will show you the hour not only during that day, but during five or six successively; without any considerable Errors, for

you have nothing to do but to erect your *Stick*, as perpendicularly as you can, and to measure its *Shade* with it, so that finding the length of the said *Shade* to be, suppose 200 i. e. twice as long as the *Stick*, your Paper will tell you, that when this proportion happens, 'tis either eight in the *morning*, or four in the *afternoon*.

OPERATION. V.

How to take an Angle in Altimetry by the Globe.

THIS Operation is to be perform'd like that of finding the height of the *Sun* and *Moon*, when they shine not out, * *Op. 2. Sect. 1.* as I formerly * show'd you; that is to say, you must place your *Globe Horizontal*, and having turned the *Meridian* towards the *Tower*, move your Eye along the said *Meridian*, till the *Extuberancy* of the *Globe* permits you only to see the top of the *Tower*, and then bring but your *String*, (which we suppose you hold in both hands cross the *Meridian*) towards you, till it just takes away the sight of the said Top, and the *Degree* which your *String* then lies on, (counting from the *Zenith*) is that of the required *Angle*, to wit, of the *Angle* which is ordinarily taken by any *Quadrant*, *Jacobs Staff*, &c.

OPERATION VI.

How to make and figure the Quadrant of Proportion, as also the Demonstration of the foregoing Operations.

IT appears plainly by the *Schema* here before us, that the *Shade* (A B) being *Radius*, the *Perpendicular* (C B) is *Tangent* of (A v. g. 14.) the *Degrees* of the *Sun's* height, as also that the *Perpendicular* (C B) being *Radius*, the *Shade* (A B) is *Tangent*.

SECT. V.

Of Dialling.

*A preliminary
Discourse.*

THE Performance of this Section no less appertains than the rest to our Globe, since it not only represents to our view, what *Dials* are in themselves, and why they shew us the time of the Day, but afford's us also so natural and so easy a way of describing them, that no person can be hardly so ignorant, who will not (with the least Instruction) in three hours time be able to make one on most *Planes*, unless perchance, for want of a little Digestion and private practice, the Rules throve one another out of his Memory. Nay all the accidental Requisites to *Dialling* (being these that follow) are here performed without the help of any torrein Instrument.

1. To draw a Meridian Line.
2. To draw a Line Parallel to the Horizon on a Plane not Horizontal.
3. To find the Declension of a Plane.
4. To find how much a Plane Reclines.
5. To find how much a Plane Inclines.
6. To find how long the Sun shines on a Plane, that is to say, when he's come on, and when He'll go off it, at any time of the year.

Besides we have already taught you, how to know when a Plane is *Level*, how to find the *Height* of the Sun, and how his *Azimuth*, all which properly appertain to this Science.

These then are the *Operations*, I mean by Requisites, which shall be all treated of either immediately before, or immediately after each *Dial* that requires them. But tho' I intend to shew you, as I now mentioned, this easy and natural way of *Dialling*, even in what bignesse you please without need of *Quadrant* or *Scale of Reduction*, without your knowing the least *Problem* in the *Mathematics*, or my requiring any thing else of you, say that you can draw a Line from Point to Point, and describe a Circle, when the Radius is given; I say, tho' I intend this,

yet

* pag. 4.

† pag. 5.

* pag. 10.

yet that you may not be wholly Ignorant of their *Geometrical Construction*, I shall teach you that also, and therein per chance something both expedite and new; but then I must suppose (for I have not time to instruct you,) *that you can Erect a Perpendicular, draw a true Parallel, and know so much of the * Sector as how (besides the use of the Line of Lines) so find the Chord and Sine of any Number of Degrees by it.* I mention the Sector, not that any Ordinary Ruler, with a *Line of Sines, Line of Chords, &c.* is unsufficient, but because you have under the Pedestal of your Globe a Sector to your hand, which I have order'd there for two Reasons.

First it will be necessary, the *Globe* standing erect and at right Angles with the *Horizon*, to bring the edge of its Pedestal to your Plane in several Operations; Now seeing this cannot be done unless the Pedestal be greater than the *Globe's Diameter* (which would, make it per chance cumbersome, and to take up too much room) there are therefore under it two small wooden Rulers about half an Inch Broad, to slip in, or out to a determin'd length, so that it will be better to have one of them a Sector (which is a very necessary Instrument) than not, especially since 'tis no hindrance to the use, we chiefly intend it for. Nor would I have any thing more on it (to avoid the Confusion of Divisions) than the *Line of Sines* on the one side, and the *Line of Lines* on the other, and as for its length, if it be six inches, it will make an even Foot at full extension, which renders it a very convenient standing measure. My second Reason for the said Sector is, because I will show you, *how to find by it the TANGENT and SECANT of any degree even according to any Radius*, and how usefull an Operation this is (and particularly in *Dialing*), every body well knows that has the least insight in it.

Suppose then you desire the *Tangent* and *Secant* of 50 Degrees; open your Sector, and taking (GR) the given Radius between your Compasses, put it over in the *Line of Sines*, at the Sine of 40, viz. at the Complement of the Angle required, and the distance between the Figures of 50 and 50, will be the *Tangent* sought for; and the distance between the Figures of 90 and 90 will be the *Secant* of the said 50 Degrees.

These two Problems I recommend to you because they are extremely ingenious and useful, found out it seems a while ago by

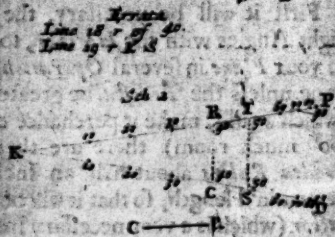
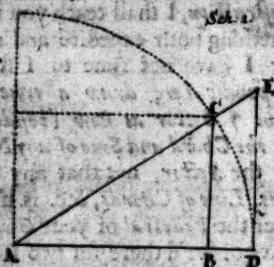
* Because every body (that desires to know these and the following Problems) has not per chance as hand Mr. Gunter's Book, I shall add them to this Treatise as the Reader will find at the end of it: J. Moxon.

by Mr. *Line* (the Author of that admirable *Horological File in White-Hall Garden*) as, since his death, one of his Scholars (that hinted them to me) informed me, and upon consideration I found them exactly true, having thus demonstrated them.

Demonstration.

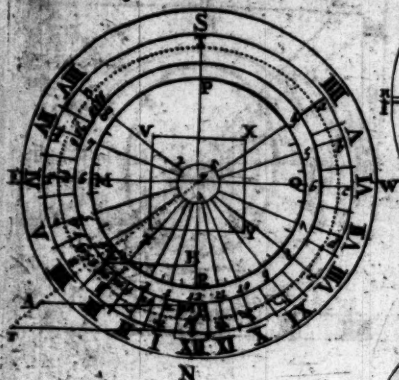
'Tis evident by *Sch. 1.* that as the Sine Complement *AB* is to the Sine *CB*, so the Radius *AD* is to the Tangent *ED*. Again 'tis evident by *Scheme 2.* that as *KC : KS :: CR : ST*, but by Construction *KC* is on the Sector the Sine of 40 or Sine complement of 50, and *CS* the Sine of 50 it self, therefore *CR* being the Radius given, *ST* must be the Tangent requir'd, viz. the Tangent of 50, according to that Radius. On the other side we see by the said first *Scheme* that as the Sine Complement *AB* is to the Radius *AD*, so is the Radius *AC* (or *AD*) to the Secant *AE*. Again you see by *Scheme second*, that *KC : KD :: CR : DP*, but by construction *KC* is the Sine of 40 or Sine Complement of 50, and *KD* is Sine of 90 or Radius of the Sector, and *CR* is the Radius given, ergo *PD* must be the Secant required.

Having thus done with the *Preliminaries*, we'll now come to the business it self, after I have told you there are five principal *Planes* on which a *Dial* may be made; to wit the *Horizontal*, the *Vertical*, the *Declining*, the *Reclining* and the *Inclining Plane*; and first of the *Horizontal*, since that *Dial* is the Basis and Foundation of all the Rest.

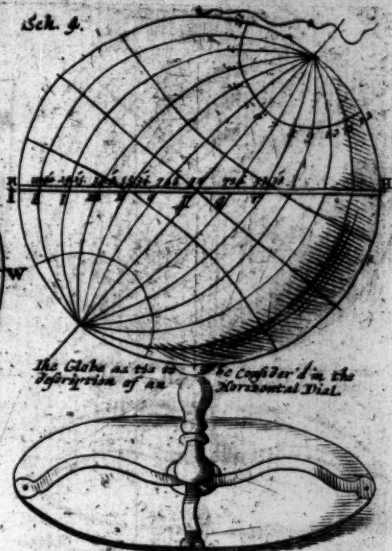


Sch. 3.

An Horizontal Dial Describ'd
by the Globe.

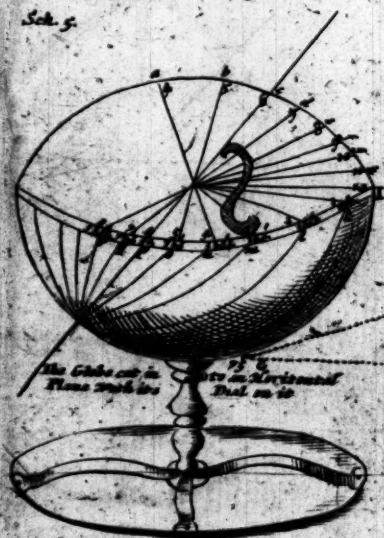


Sch. 4.



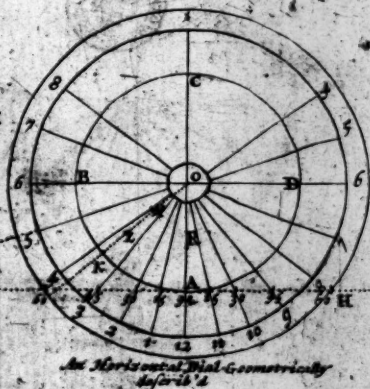
The Globe as it is
describ'd in the
Horizontal Dial.

Sch. 5.

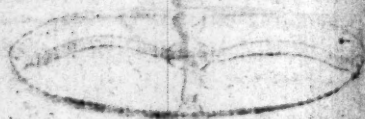
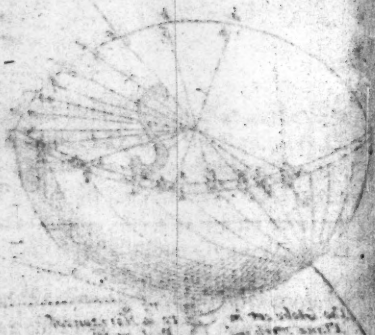
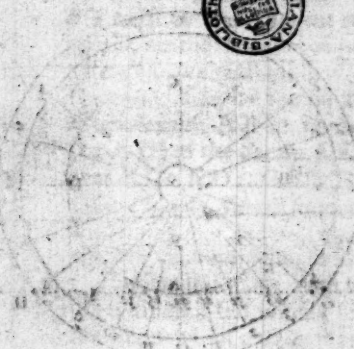
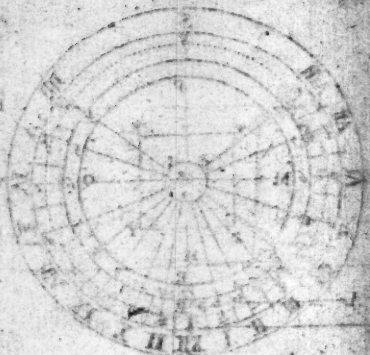
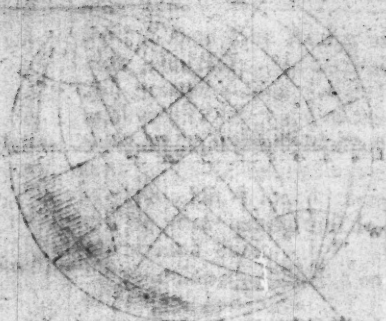


The Globe cut in
Plane parallel to
the Horizontal
Dial as it is

Sch. 6.

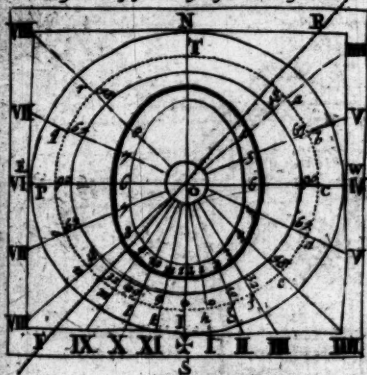


An Horizontal Dial Geometrically
describ'd

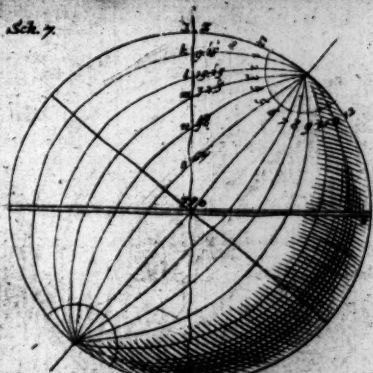


Sch. 10.

A Vertical South or North Dial
Refract'd by a Globe for a Climate of London



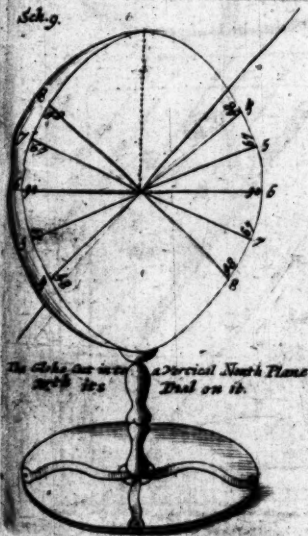
Sch. 7.



The Globe as it is to be Consider'd in the
Description of a Vertical North or S. Dial.

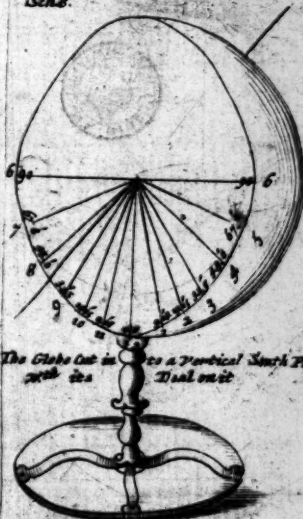


Sch. 9.

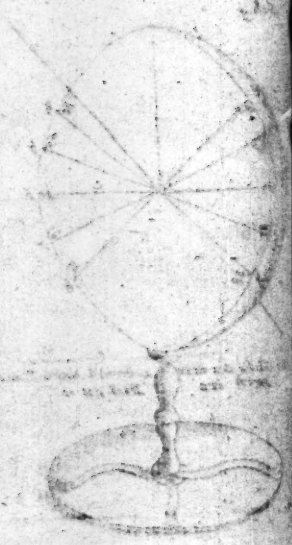
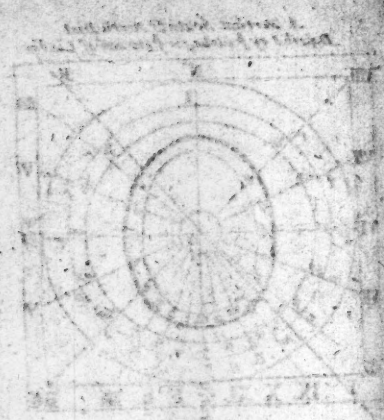
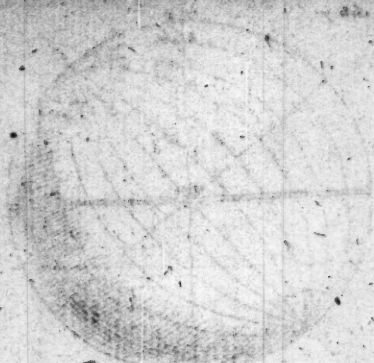


The Globe cut into a Vertical North Plane
Dial on it.

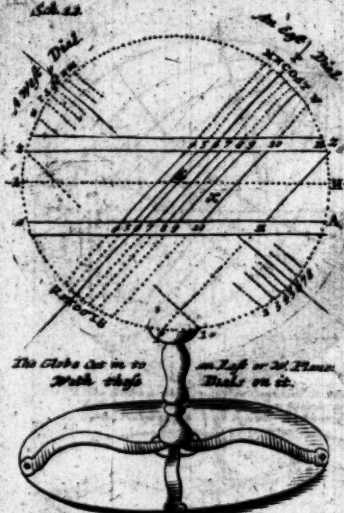
Sch. 8.



The Globe cut into a Vertical North Plane
Dial on it.



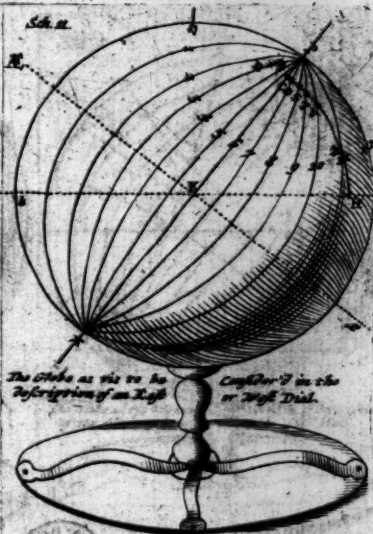
Sch. 11.



The Globe as it is to
be used

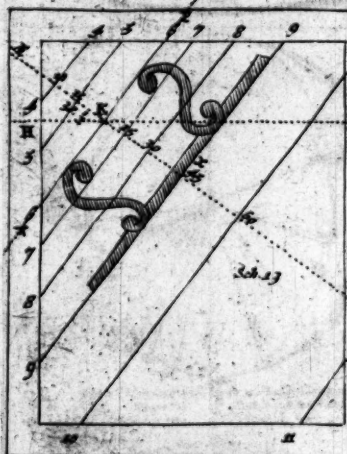
The Globe as it is to
be used

Sch. 12.

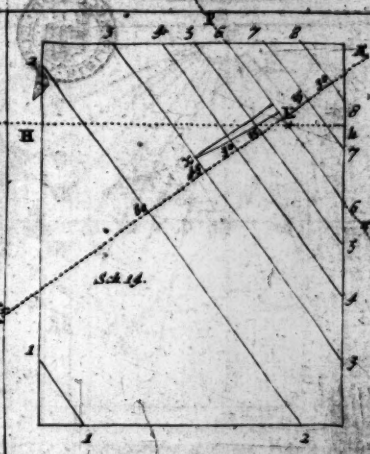


The Globe as it is to
be used

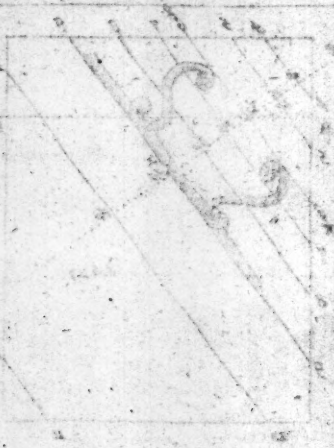
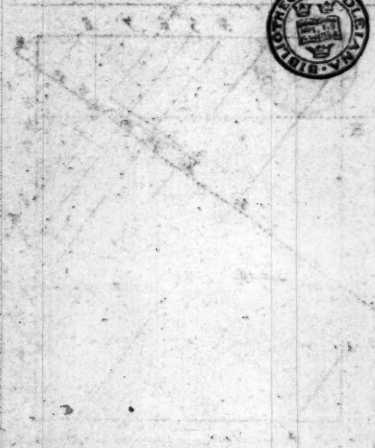
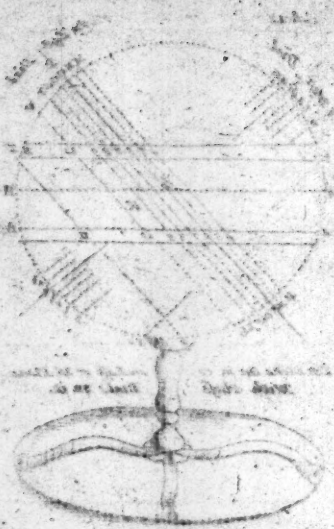
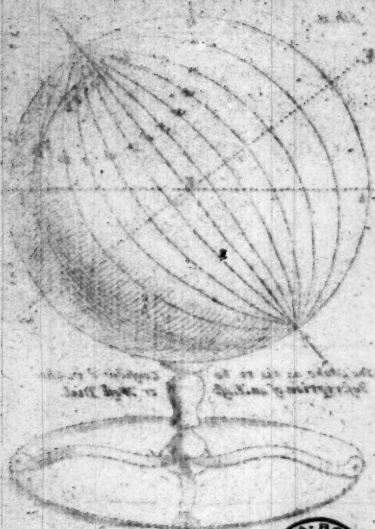
The Globe as it is to
be used

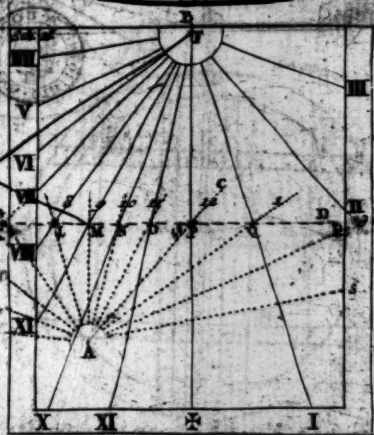
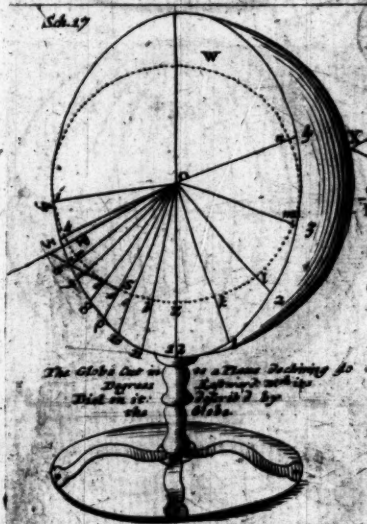
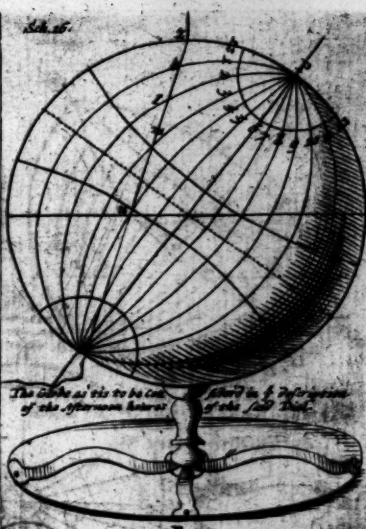
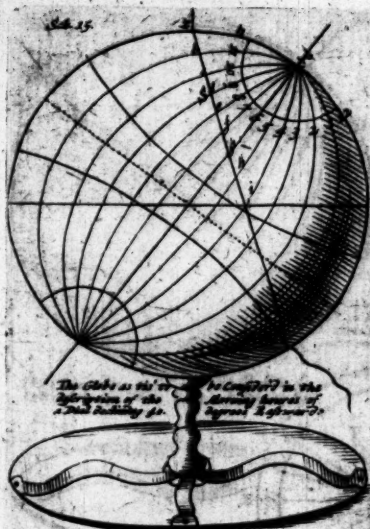


An Left Dial Geometrically
Described.

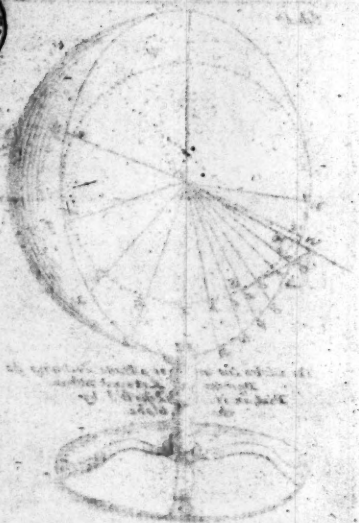
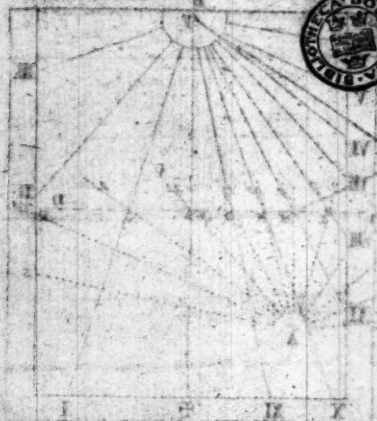
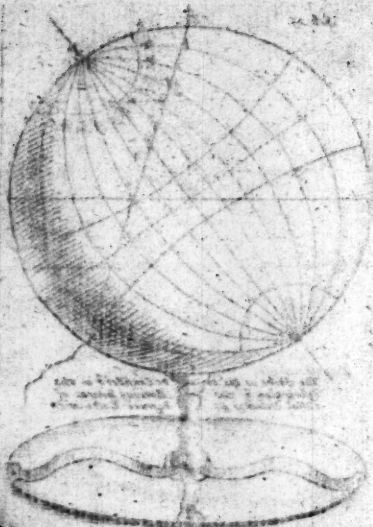
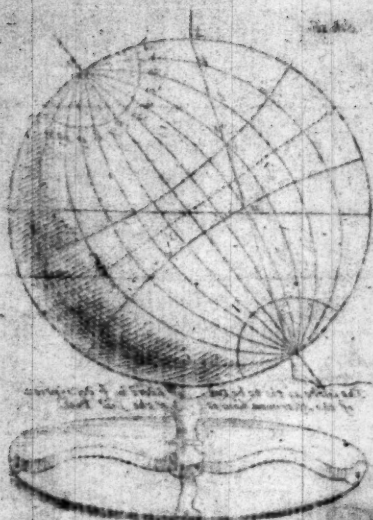


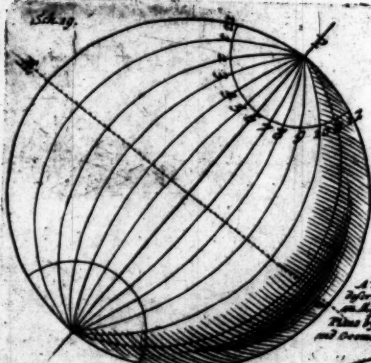
An Right Dial Geometrically
Described.



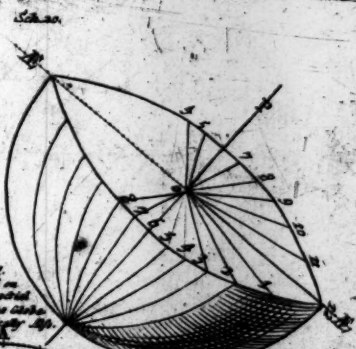


A Dial Tilted so as to be used
Geometrically.

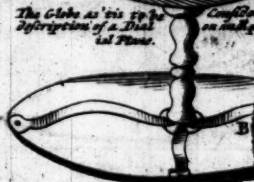




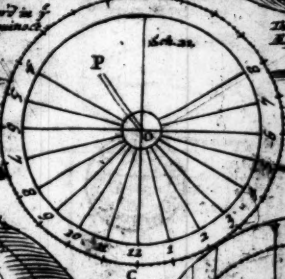
Sch. 19.
The Globe as it is to be
Description of a Dial
on the Plane.



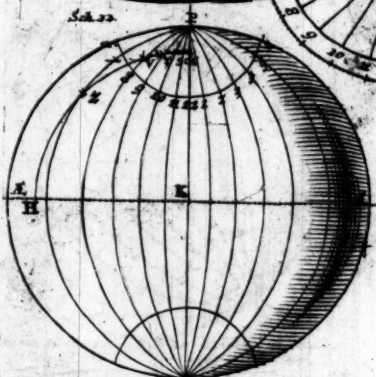
Sch. 20.
A Dial
on a
conical
Plane by the Globe
and Concomitantly.



Sch. 21.
Consider'd in
an Equinoctial
Plane.

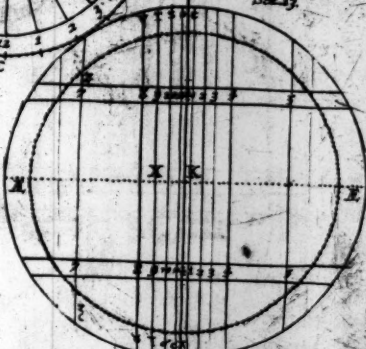


Sch. 23.
The
Globe Cut into an
Equinoctial Plane with
Dial on it.



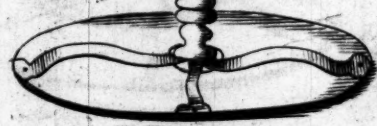
Sch. 24.
The Globe as it is to be
spherical of a Polar

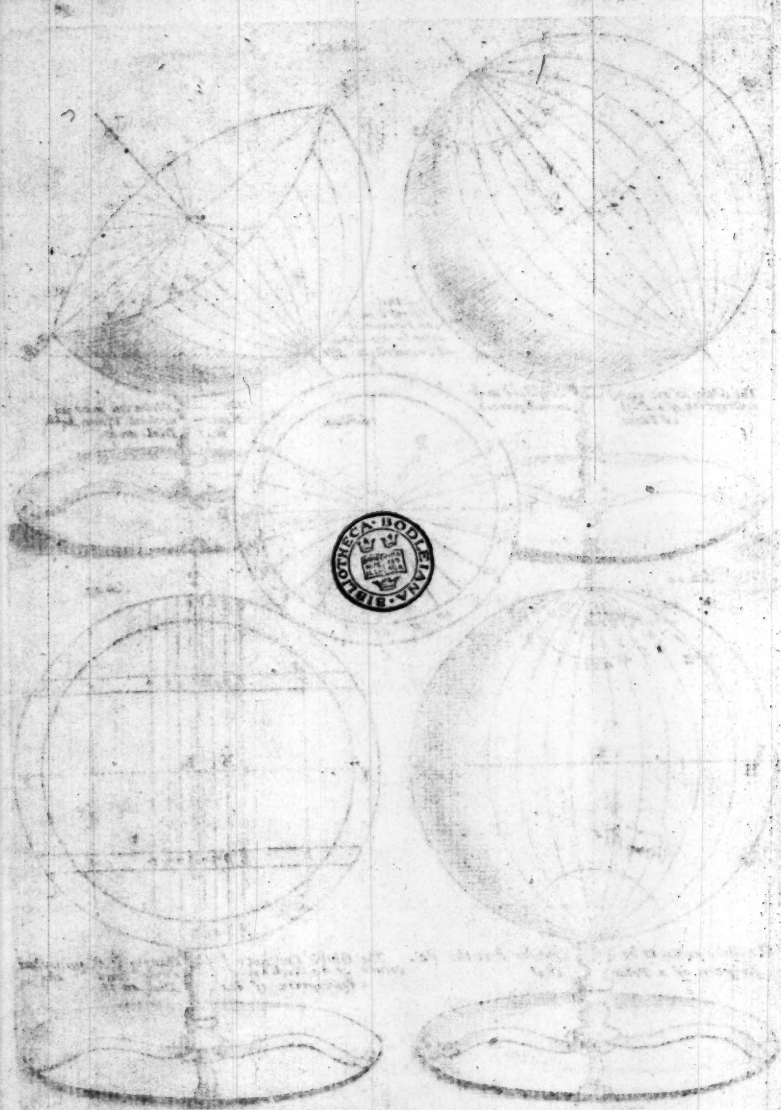
Sch. 24.
Consider'd in the
Dial



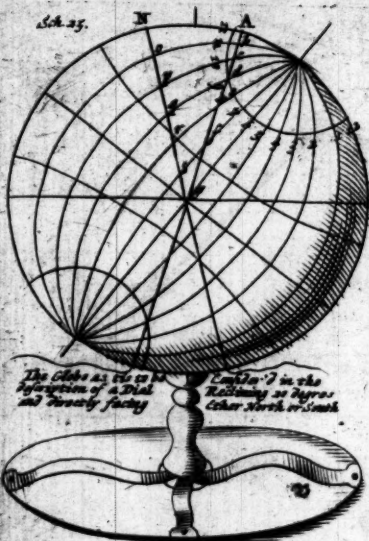
Sch. 25.
The Globe Cut into a
Plane of a Clock House
Description of the

Sch. 25.
Plane of a Clock House
Dial on it.

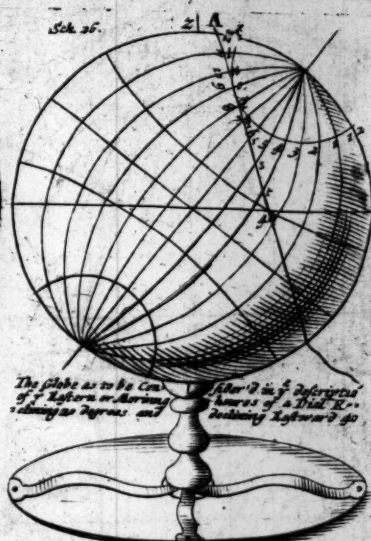




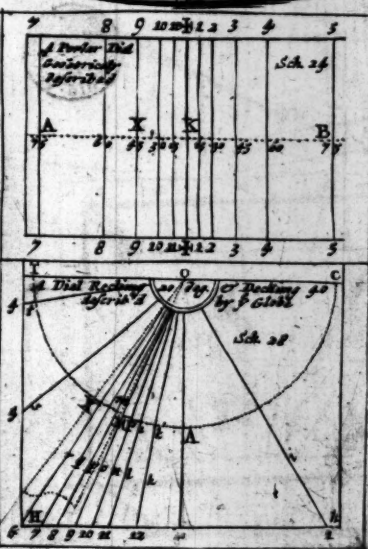
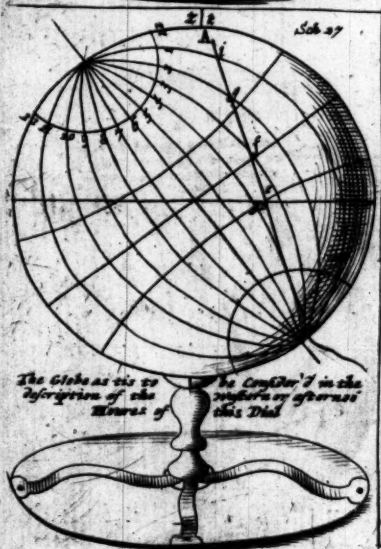
Sch. 25.

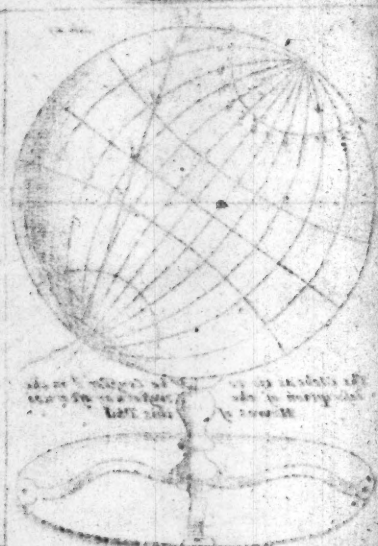
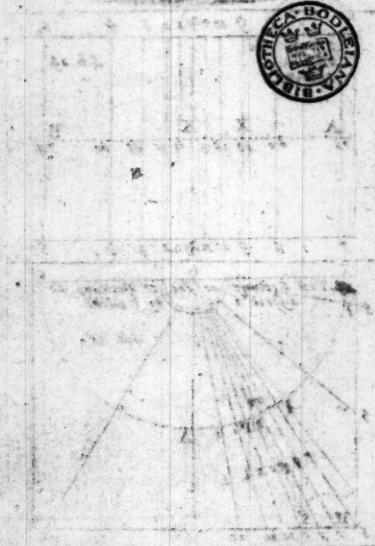
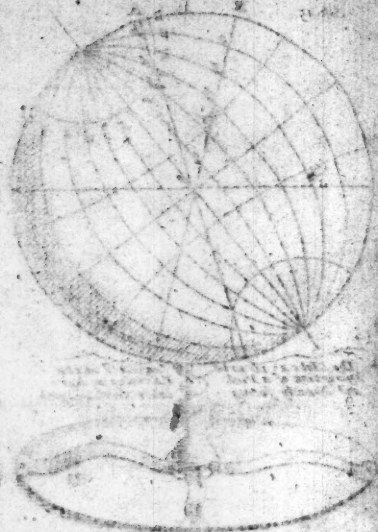
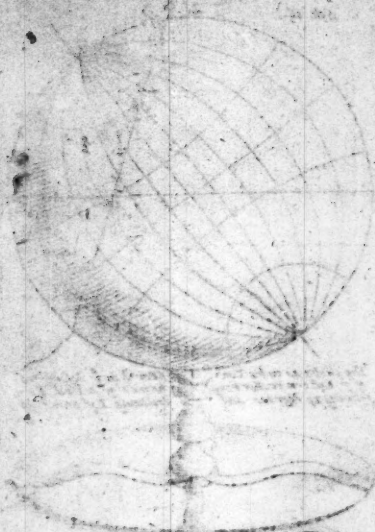


Sch. 26.



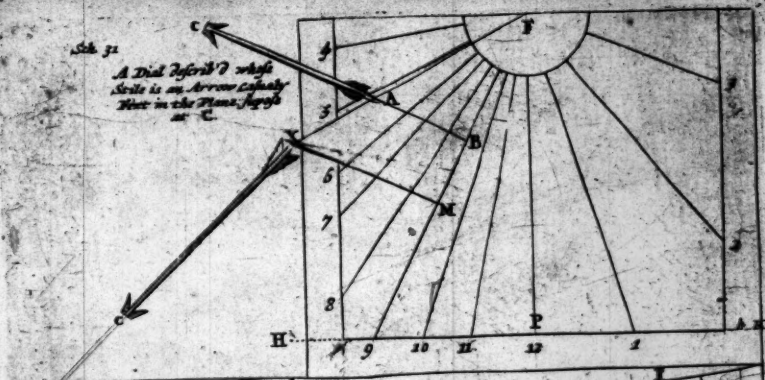
Sch. 27.





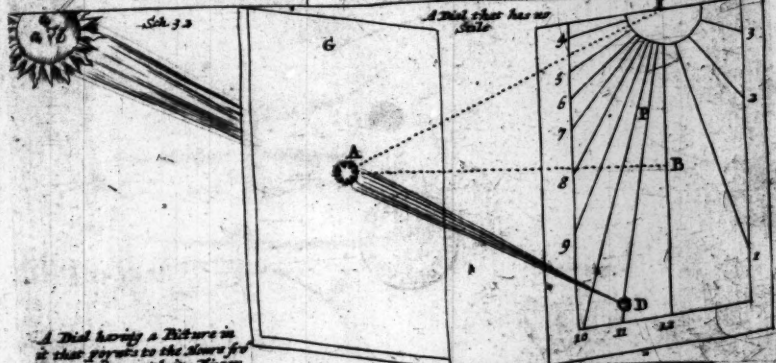
Sch. 31

A Dial Refers 7 whole
Scale is an Arrow Equally
Not in the Plane, Angles
at C



Sch. 32

A Dial that has no
Scale



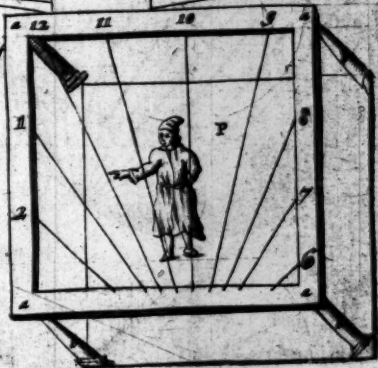
A Dial having a Picture in
it that serves to the hours for
time to time with its Finger

Sch. 33



Sch. 34

An other Dial of
the same
Picture



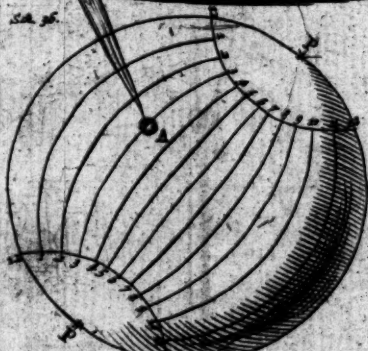


LA 35

A Wind Area Dial



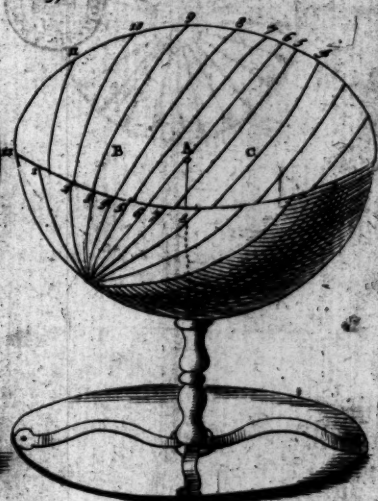
LA 36

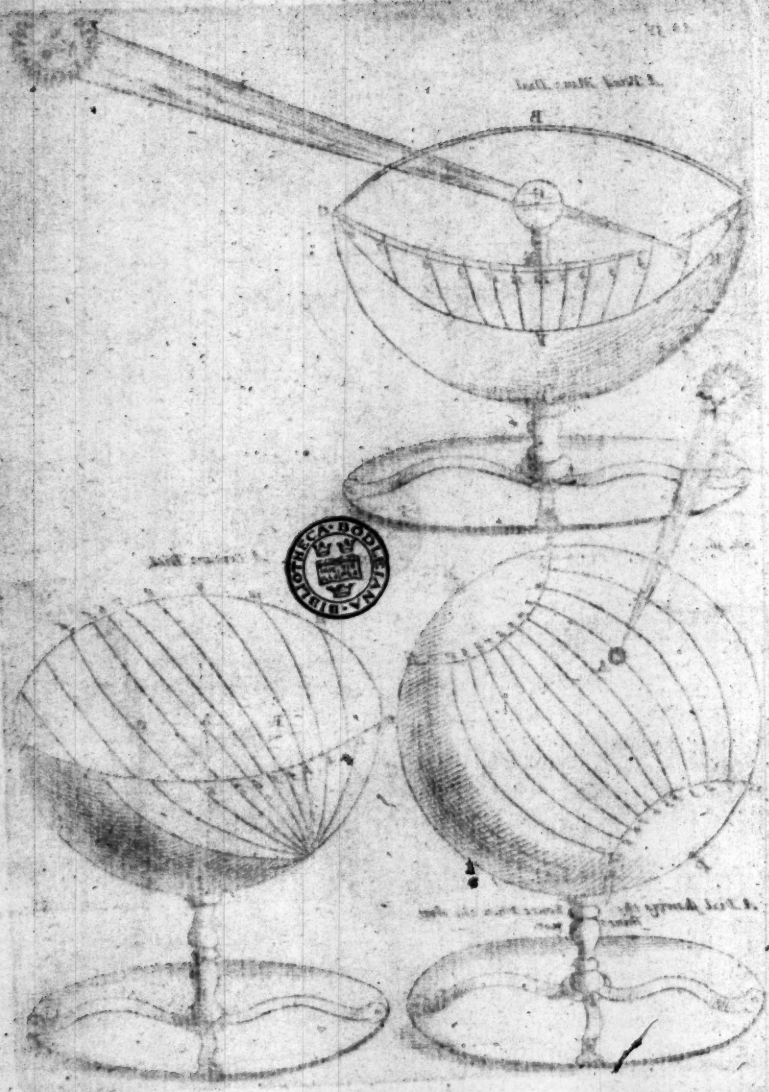


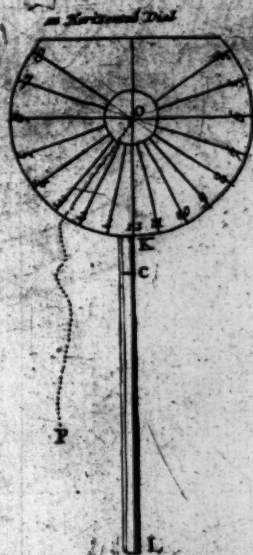
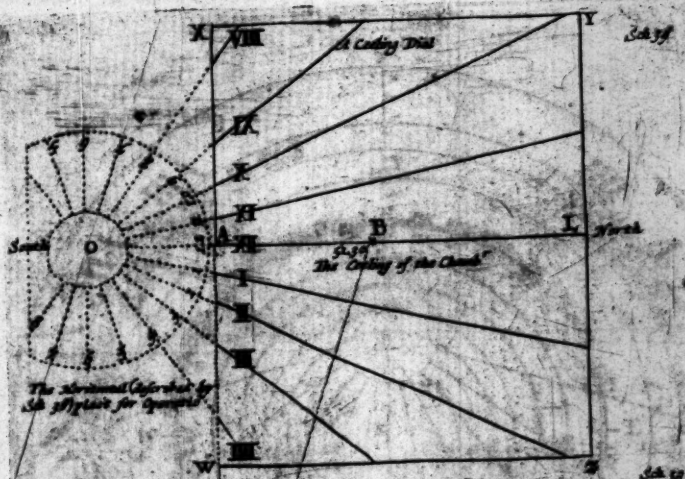
A Dial showing the place where the sun is

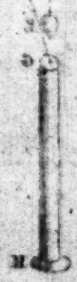
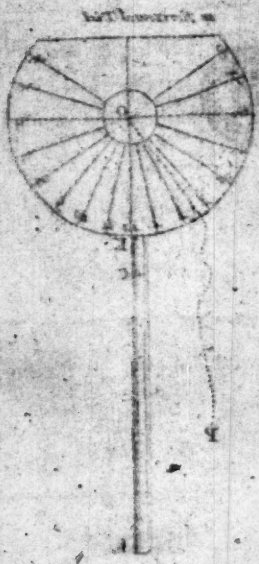
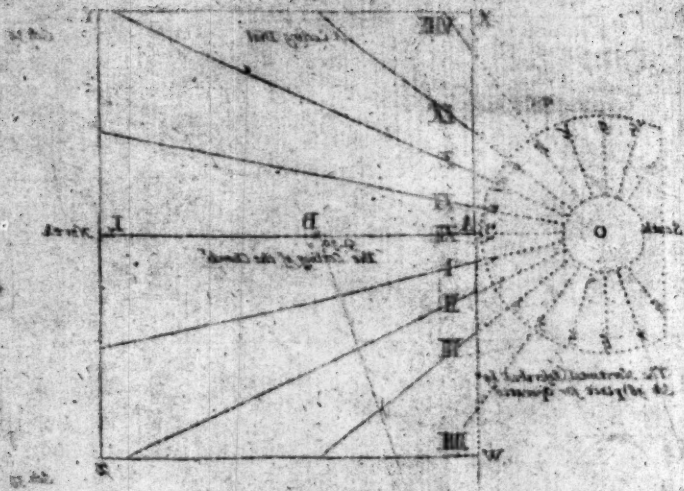
LA 37

A Conic Dial

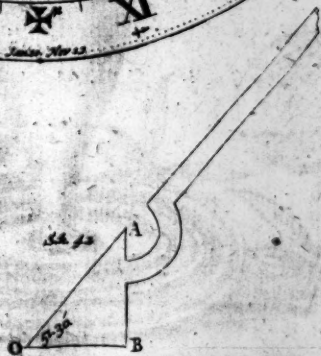
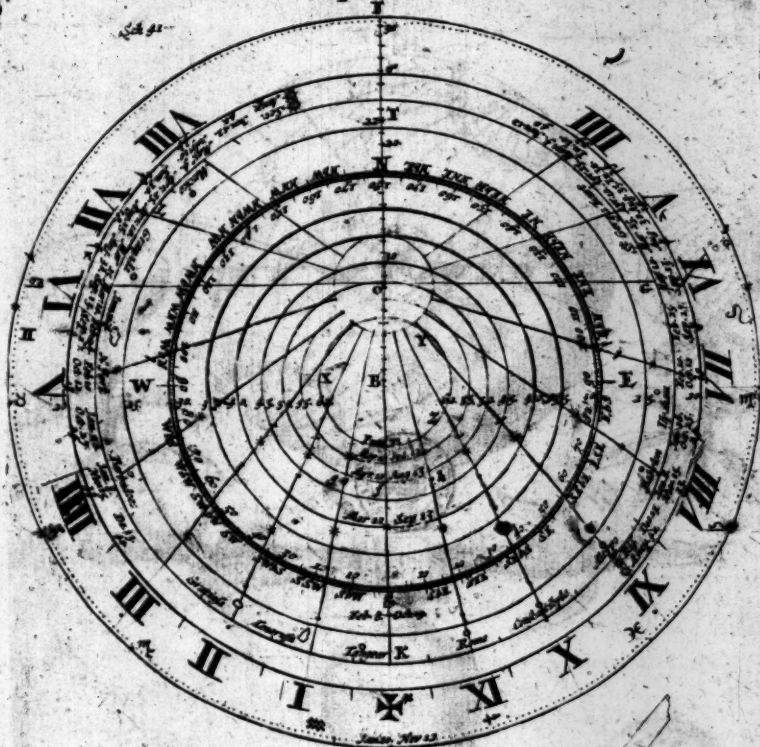


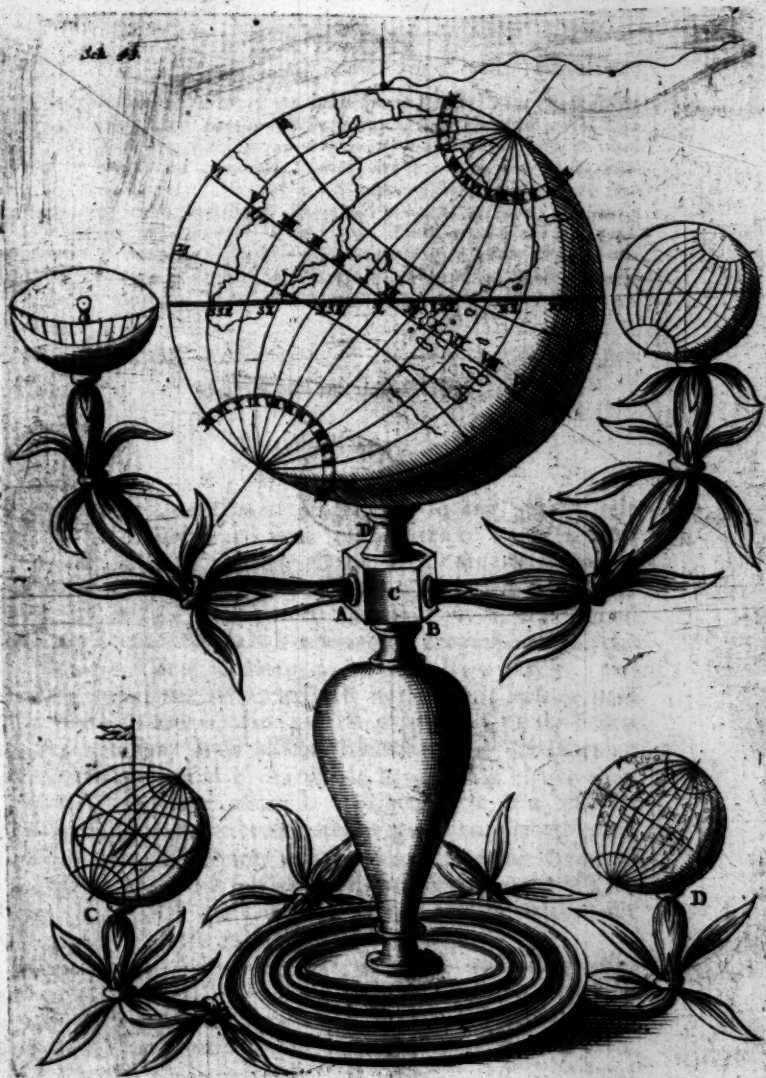


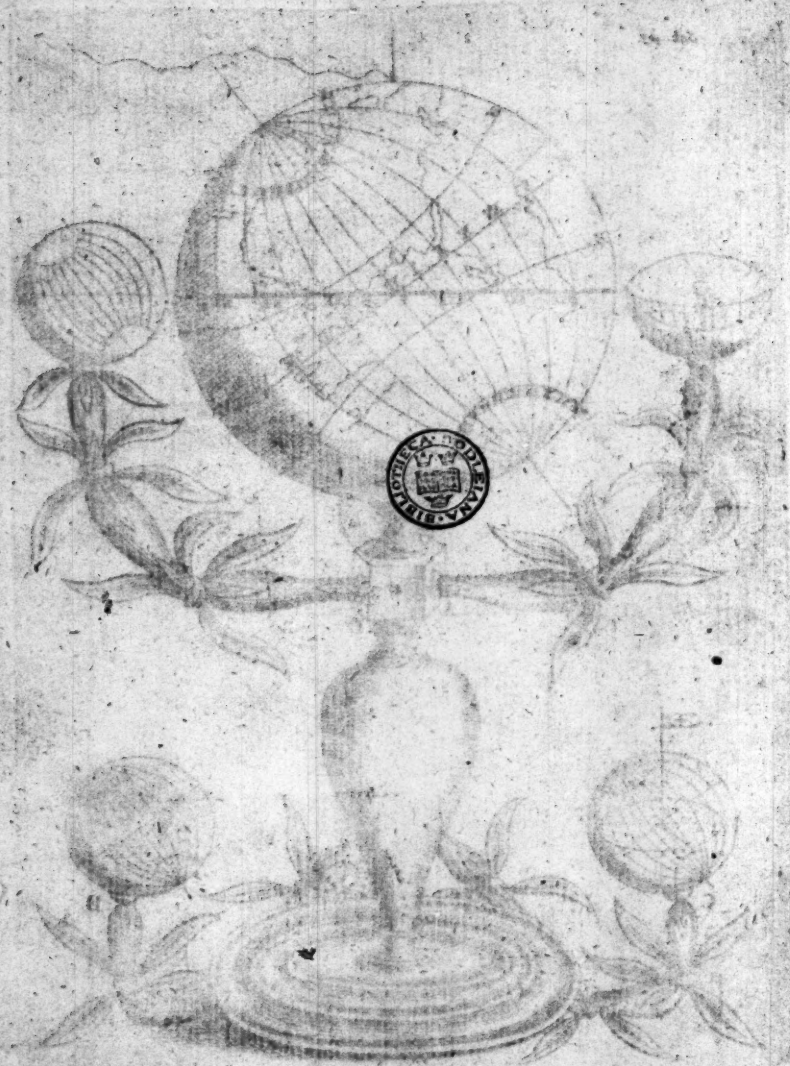




A Compound Dial







OPERATION I.

BEfore you proceed further, you must know Reader, that the Printer (skipping a line in the last Paragraph, and then adjusting the number of Planes to those he found express) has left out two, so that the before mentioned principal Planes are 7; viz. the Horizontal Plane, the Direct Vertical Plane, the Declining Vertical Plane, the Direct Reclining Plane, the Direct Inclining Plane, the Reclining Declining Plane, and the Inclining Declining Plane. First, then of the Horizontal, that Dial being (as I said) the Foundation of this Science, and afterwards of the rest in Order; for the Author treats of all Dials that are to be described on the aforesaid Planes. J.M.

A Memorandum.

How to describe an Horizontal Dial by the Globe, for the Elevation of London.

The first way.

Open your *Compasses* at 60 Degrees in any great Circle of your *Globe*, and draw on a sheet of Paper a *blind Circle* with a fair *Diameter* throu' it, for the *Meridian* or 12 a Clock hour line of your *Dial*; Then take with your *Compasses* in the *Horizon* of your said *Globe*, the several Distances between the next 8 morning or evening hour Circles and its *Meridian* or ordinary 12 a clock hour Circle, and marking these Distances successively in the *blind Circle* on both sides of its *Diameter*, they and the *Center* will be the Points by which you may draw all hour Lines from 4 in the Morning till 8 at Night; and if you would have a *Dial* bigger than the *blind Circle*, draw about it a bigger Circle, if a lesser a less: nay, if you describe any other Figure as an *Oval*, *Square*, *Oblong*, &c. the said Points will as well guide your *Ruler*, as when the *blind Circle* it self was the Extremity or border of your *Plane*. But least this Direction should be too obscure for a Beginner, I will here adjoyn an Example.

The Construction.

Having opened your *Compasses*, as I said, at 60 Degrees in any great Circle of your *Globe*, and describ'd a *blind Circle*, to wit, I p T c, as in Scheme third, draw a fair line I T any how throu' the *Center* O for your *Meridian* or 12 a clock hour

An Example.

L

hour

hour Line; and by the way remember that in the Fabrique of this *Dial* you place the point I ever towards you, and I farthest from you, to the end you mistake not when directed to this or that hand. Having then proceeded thus far, put one foot of your *Compasses* on the *Meridian* or (according to the *Polar Figures*) the 12 a clock Circle of your *Globe* where it cuts the *Horizon*, and the other foot on the 1 a Clock Circle, and mark this distance in the *blind Circle* from I towards the left hand, to wit from I to k, and it will give you a point or mark for your 1 a Clock hour line, and from I to b towards your right hand the mark for your 11 a Clock hour Line. In the next place take in the said *Horizon* the distance between the 1 and 2 a Clock Circles, and place it from k onwards to l for a mark for your 2 a Clock Line, and from b to g for the 10 a Clock line, and so on till you come to r, 8 at night, and to a, 4 in the morning, which are the latest and earliest Summer hours. If then you would have a larger *Dial* describe a larger Circle, suppose, N E S W, or if a lesser *Dial*, a lesser Circle, as M P Q R, and laying your *Ruler* on the Center O, and on each of the former Marks or Letters in the said *blind Circle* successively, draw but a fair line to the designed *Limb* or Border (whether it be a Circle, or the square V X Y Z or any other *Figure*,) and your *Dial* wants nothing but a Cock; but remember that you need not draw your hour lines quite from the Center O, because meeting all there, they will be apt to blur; therefore describe about the said Center, at what distance you please, a little Circle (like $\gamma \Delta \lambda$) and your lines will terminate there with more neatness and convenience.

Now if you have a mind to put on half hours the half hours, and quarters, you will not much err if you divide each hour into four parts, but to be exact you must make use of your *String*, thus. You know that the distance between each hour Circle in the *Aequator* is 15 Degrees, Draw therefore your *String* from the Pole throu' the *Aequator* of your *Globe*, over 7 degrees and 30 minutes, (or half the distance between each Hour Circle) and where the *String* cuts the *Horizon* there will be the true half Hour of that Hour, so that if you mark with your *Compasses* the said distance on the *blind Circle*, between the corresponding hour lines, the *Ruler* (passing

How to draw
the half hours,
and quarters,
quarters, &c.

sing throu' that *Mark* and *Center*) will give you in the Border the place of that *half hour*; and in like manner you are to proceed in marking out the rest, as also the *Quarters*, and all other *Subdivisions*.

As for the *Stile* or *Cock* of this *Dial*, it must always at the *Center* make an *Angle* with the *Meridian* or 12 a *Clock Line* ($O I$) equal to the Distance between the *Pole* and the nearest part of the *Horizon* of the *Globe*; that is to say an *Angle* equal to the *Elevation* or *Latitude* of the Place; therefore your *Dial* being made (suppose) for *London*, open your *Compasses* at the aforesaid distance, or at 51 Degrees and $\frac{1}{2}$, and placing one foot on I , the other will fall on K in the said *blind Circle*; so that drawing the *blind line* $O K$ to π , you will have the *Triangle* $I O \pi$, which if you so erect, that the Point O lyes just on the *Center*, and the Base $I O$ on your 12 a *Clock line* (or *Substile*) your *Dial* is finish'd.

And here you may take notice, that tho' this *Stile* be the *Triangle* $I O \pi$, yet you may fashion it into what shape you please, in case the side πO (which indicates or shows the *Hour*) makes still an *Angle* of 51 Degrees and $\frac{1}{2}$ with the *Meridian* $I O$; nay, you may make it a *Pin* or upright *Stile*, as appears by the *Perpendiculars* $A B$, $G H$ and πI , for either of them will serve the turn by marking the hour with the shade of its *Apex* or *Top*: but then they must not be plac'd in the *Center* O , but thereon the *Substilar*, where (falling from the *Indicating side* $O \pi$) they stand Perpendicular to it; that is to say, the *Pin* $A B$ (being part of the *Triangle* or *Stile* $I O \pi$) must be erected at B , the *Pin* $G H$ at H , and πI at I ; and the reason why they perform this Office, as well as the whole *Triangle* $I O \pi$ is, because their *Tops* are parts of the *Line* $O \pi$, which is the only side of the said *Triangle*, that shows the *Hour*, as we mention'd before. Now for the *Demonstration* of all, it follows in the next *Operation*.

OPERATION II.

How to describe an Horizontal Dial by the Globe for the Elevation of London.

The second way.

The Construc-
tion.

Describe a Circle of what bigness you please, and draw a Meridian, or 12 a Clock line throu' it, as before; then count in the Horizon of your Globe how many Degrees there are between the Hour-Circles of 12 and 1, or, (which is the same thing) between 12 and 11, and you will find their number to be about 11. 40'. These place on both sides of your said Meridian Line by the help of a Quadrant, or Line of Chords, and they'll give you (if you lay your Ruler as before on the Center) the 11 and 1 a Clock Hour Lines of your Dial, to wit, the distance from I to k, and from I to h, as may be seen in the aforesaid third Scheme. Proceed then in this manner as to the rest of the Hour lines, and for your Style and Substyle, the former Directions are sufficient.

Demonstrati-
on.

The Demonstration or Reason why these Dials show the Hour is not difficult; for if you consider your Globe, you will see that all its Hour-Circles are equally distant from each other, and that the Axis of the World (of which the two Poles are the extremities) lies in the middle of them, and is in truth a part of each, as being the common Section of them all; therefore when the Sun comes into the Plane of any Hour Circle (for example to that of 4 in the morning) the shade of that Hour Circle will fall there, where the said Hour Circle cuts the Horizon on the Opposite or Western side, and consequently the Axis being in that Plane, as a part of it, its Shade must needs fall there also. Now since the Blind Circle or Limb of the Dial described is a Circle representing the Horizon, and having by Construction its Hour-lines distant from each other as the Hour Circles of the Globe or World are distant in their Horizons, and since the Hour-lines of This (and consequently of all other Dials) are only the

in-

intersections of the *Hour-Circles* with their respective Planes, it must needs follow, if we place in the middle of the said *Dial* a *Cock* or *Stile*, making an *Angle* of 51, 30, with its *Meridian line* or *Substilar* (to wit, the *Angle* which the *Axis* of the *World* makes with the intersection of the *Meridian* and *Plane* of the *Horizon*) 'twill cast a *Shade* directly on the *Hour line* corresponding to the *Hour Circle* in whose *Plane* the *Sun* then lies, in case the *Meridian* or 12 a *Clock line* of the *Dial* be plac'd *North* and *South*, like the *Meridian* of the *Globe* when compos'd; for the *Globe* it self without it be compos'd will not (as we have formerly mention'd) shew the *Hour*, because its *Hour-Circles* do not then correspond with the *Heavenly* ones. And as for the reason why the 12 a *Clock line* is the *Substilar*, 'tis because the true *Height* of the *Axis* above the *Plane* (which the *Stile* or *Cock*, as I shew'd you, represents) is to be measured in the *Hour Circle* that falls on the *Plane* at right *Angles*, which being the *Meridian* or ordinary 12 a *Clock Hour Circle*, it follows that its Intersection with the *Plane* must be the *Substilar*, or *Line* with which the *Stile* is to make the *Angle of the Elevation*.

All that we have then said of this *Dial* may be clearly seen by *Sch. 5.* which represents your *Globe* cut into an *Horizontal Plane*, with its *Dial* on it, as *Sch. 4.* does the *Globe* entire, when you consider it in the description of the said *Dial*; for there you have before your eyes (by the Letters *I k l*, &c.) not only how to open your *Compasses* from *Hour-Circle* to *Hour Circle* for the true placing the *Distances* of each *Hour-Line* on your *blind Circle*, but also the number of *Degrees* in the *Horizon* between every *Hour Circle* and the *Meridian*. Besides, by the *Horizons* oblique cutting the *Hour Circles*, you may see how that (notwithstanding the equality of the *Suns* Horary motion) the *Hour-lines* of this *Dial* must be unequal, and consequently that they are of different distances in different *Latitudes*.

OPERATION III.

To describe an Horizontal Dial Geometrically, for the Elevation of London.

Describe a fair Circle as ABCD, and if you would have your Dial of another Shape, you may afterwards describe about it what Figure you please; I say, describe the fair Circle ABCD, and draw throu' its Center O the Line AOC for your Meridian or 12 a Clock hour line, and crossing it at right angles with BD for the Morning and Evening 6 a Clock hour lines, mark in it (by the help of your Line of Sines or any way else) from A the value of 51. 30. or Latitude of your dwelling, which happening to reach, (for example sake) to K, draw the blind line OK, then throu' any point of AO (suppose A) draw GH, another blind line, parallel to BD, or at right Angles with the said AO, and taking with your Compasses the nearest distance between A and OK, which being (suppose) the point L, let AL, by the help of your Sector (according to our former^d directions,) be the Radius to the Tangent Line GH, so that marking in it on both sides of A, the Tangents of 15, 30, 45, 60, and 75 Degrees, the said Center O and the point 15 will give you the Hour-lines of 1 and 11, the Center O and 30, those of 2 and 10, and in this manner proceed to 75, which will give you the Hour-lines of 3 and 9, and as for those beyond the 6 a Clock lines, do but produce 8 in the Morning, and 'twill give you 8 at Night, and 7 in the Morning 7 at Night, as will 4 and 5 in the Evening, the like forenoon Hours.

Thus then you have not only an Horizontal Dial Geometrically described, almost as soon as the former, (and this without embroyling the Plane with multiplicity of blind Circles and Lines) but a way also (in case you have no Sector) how to make any Tangent Line serve your turn; for, 'tis but taking between the Compasses 45 Degrees of it (i.e. a distance equal to its Radius) and finding out (by a trial or two) the Point (sup-

(suppose) R in the line O A, where one foot of your *Compasses* being placed, the other just touches M (the suppos'd nearest point or distance in O K from the said R) draw throu' R a line at right Angles with the *Meridian*, and noting in it, as we shou'd you before, the Degrees of each hour (according to this new *Tangent line*) the Center O and these Degrees will give you the points of each hour line; for as the former *Radius* A L was to the several Degrees in its *Tangent Line*, so will the now *Radius* R M be to the several Degrees in its *Tangent Line*.

As for the *Demonstration* or Reason of this *Dial*, every body *The Demon-* that understands *Gnomonics* comprehends it, I doubt not, at the *stration*. first sight; for the Angle O in the Triangle K O A, being by construction equal to the *Elevation*, do but place the Base A O on a *Meridian Line*, and if you consider the Side K O as the *Indicating Side* of the *Stile* or *Cock*, it necessarily follows, that it will represent the *Axis* of the World; for it is evident that its Top K will point directly to the *Pole*, and touch it, if produc'd, whilst O its other extremity passes throu' the Center of the *Horizontal Plane*; therefore if a Circle (whose *Radius* is A L) were so plac'd on this *Stile* or *Axis*, that its *Diameter* crost it at right Angles at L, the said Circle would represent *Circulum maximum semper apparentium*, for that Circle in the Heavens ever touches the *Horizon*, as this would do at A. This Circle then being parallel to the *Equator*, is divided by the *Hour Circles* into twenty four equal parts, and consequently each fifteen Degrees in its *Tangent Line* G H, will correspond with its said equal parts or Divisions. Now G H is also the *Tangent Line* of the *Horizon*, as touching it in the Point A, but where the *Hour Circles* cut the *Horizon*, or its *Tangent line*, there the Points will be, to which (from the Center) the *Hour Lines* in an *Horizontal Dial* are to be drawn; ergo O the Center of your *Horizontal Plane*, and the several fifteen Degrees in the common *Tangent* G H are the true points of the *Hour Lines*. Besides as the distance between each *Hour Line* (if A L be the *Radius*) is 15 Degrees, so if A O be *Radius* (I mean O A the *Radius* of the *Horizontal Plane*) the said *Hour Lines* will be distant as many Degrees asunder, as they are in the *Horizon* of the World, or as you found them in the *Fabrick* of the second *Horizontal Dial* by the *Globe*. Here also you may see, that the true place of this *Dial* is to be in the Center of the Earth, and not

not on its superficies, but by reason of the *Suns* vast distance, the Error, which thereby happens) is not sensible; nay, because the Error is not sensible, we may safely conclude, *that the Sun is vastly distant from us.*

* pag. 4.

A Memorandum.

So much then for *Horizontal Dials*, since there now remains nothing necessary to be known, but how to find whether they stand *Level* or no (which is handled in the first * *Section*) and how to draw a *Meridian Line* for their true placing, which is learnt by the following *Operation*. But before we go further let me advise you (whensoever you make a *Dial* of consequence, of what kind soever it be) to describe it first on *Paper*, and thence to mark out the *Lines* on your real *Plane*, for thereby you will not only keep your said *Plane* neat, and more judiciously chuse the best place for the *Center* of your *Dial*, but (besides the several conveniences which practice will show you) the *Lines* themselves will be more exactly drawn, by reason you can manage your *Paper* draught as you please.

OPERATION. IV.

How to draw a true meridian Line on any Horizontal Plane.

* pag. 3.

* **C**ompose your *Globe* on the *Plane*, or Place where your *Dial* is to stand, and making marks or pricks there (on each side of the *Pedestal*) at the *Letters S and N*, draw but a *Line* throu' those marks, and that will be a true *Meridian Line*, and if you do the like under the *Letters E and W*, you will have a true *East and West Line*.

OPERATION. V.

How to Describe a Vertical, or an Erect Direct South Dial by your Globe for the Elevation of London.

The first way.

THIS *Dial* is made on the *Plane* of the *Primary Vertical*, which passes from the *Zenith* to the *Nadir* throu the *East* and

West points, and being therefore erect, and facing also directly the South, 'tis commonly called an Erect Direct South Dial; so that if you draw but your String from the Zenith to the Nadir thro' either of the Intersections of the Horizon with the Equator, 'twill appear upon the Superficies of the Globe, like the emerging edge of a thin Plate, and consequently represent the said Plane, or at least as much of it as is requisite.

This being done, open your Compasses at 60 Degrees, as * before, and describe on a sheet of paper the blind Semi-Circle I P C (as in Scheme 10) with the Diameter or Meridian I O T throu' it, then take with your Compasses the distance between the Zenith of your Globe, and the Intersection of your String with the nearest Hour Circle, and 'twill in your Blind Circle on both sides of the Meridian or twelve a Clock Line, (to wit from I to k, and I to h) give you marks, by which you may draw from the Center O the Hour Lines of 1 and 11; as will the distance from k to l, and h to g (viz. the distance from the said first Intersection to the second) the marks of 2 and 10; and in this manner you must proceed to 6 and 6, as the latest and earliest hours, that this kind of Dial shows, for since its Sides lye full East and West, and that the Sun never comes to the East before 6 in the morning, nor is later in the West than 6 at night, 'tis impossible that the Plane should significantly contain more Hour-Lines. And as for the Style or Cock, the distance on your Globe between the Zenith and the Pole (being the Complement of the Elevation) gives you from I to K the Degrees of its height above the Plane, so that you may easily place and erect it, the Substyle being still the Meridian. The Rules in the first Horizontal Dial will show you also both how to contract and enlarge it, and how to resolve (especially if you consult the 7th, 8th, and 10th. Schemes) any difficulty that can possibly arise in the present Operation; for Scheme the 7th. shows you the Globe it self with the String drawn from the Zenith to the Nadir throu' the East Intersection of the Equator with the Horizon; and Scheme the 8th. the Globe cut into this Plane by the said String, and lastly the lower part of Scheme the 10th. (to wit, the Semi-Circle P I C) the Dial described by the foregoing Directions. Now for the Demonstration it follows in the 8th. Operation.

The Construction.
* pag. 73.

OPERATION VI.

How to make this Vertical South Dial by the Globe for the Elevation of London.

The second Way.

The construction.

DEScribe a *Blinde Circle* of what bigness you please with a *Diameter* throu' it, and placing your *String* on the *East* or *West* Poynt of the *Globe* as before, measure (by your *Beador Compasses* in any great Circle) the distance between the *Zenith* and each *Interfection* of the said *String* with the *Hour Circles*, and you will have the *Degrees* of every *Hour* from 12 a Clock, as the before mentioned *Seventh Scheme* shows you, so that by the help of your *Sextor* (or of any *Line of Chords* or *Quadrant*) you may mark them successively in your *Blind Circle* on both sides of the *Diameter*, and then if you draw from the *Center* *Lines* throu' those marks, your *Dial* is finish't; for as to the *Stile* and *Substilar*, you need no other *Instruction* than what you had in the last *Operation*, which also directs you to the *Demonstration*, since the same serves both.

OPERATION VII.

How to draw a Line Parallel to the Horizon; together with two ways how to place truly all paper Draughts on their respective Plane.

• pag. 79.

How to draw a Line Parallel to the Horizon, and how to place truly the draught on its Plane

HAVING lately advised you *To Delinate all Dials on * Paper*, before you draw them on your designed *Plane*, and having shew'd you how to describe this *Dial*, 'tis now time to teach you how to draw an *Horizontal Line* on this *Plane*, that you may thereby truly place your *Draughts*. Slip therefore out your two *Rulers*, which are under the the *Pedestal* (as I already mentioned) and placing the end of one on a convenient *Center* (chosen by you) in your *Plane*, you'll have by the end of the other (when the *Plummet* falls on the *Asterisk* or little *Star*) a

sc-

cond Point, and consequently marks to draw the required line by; so that if you then place the *Center* of your said *Draught* on the *Center* of the *Plane*, and its 6 a *Clock Hour Line* on your *Horizontal Line*, all the other *Lines* will fall on their true places, and thereby show you where (with a *Compass* or the like) to mark out points for the perfect and final drawing of them. The *Cock* also of the *Paper Dial*, will direct you in the placing of the other; for they are both to be of the same height above their respective *Planes*, with their *Tops* pointing the same way; viz. downwards to the *Horizon* in all these *South Dials*.

But if you will have yet a more easy way of placing a *Paper Draught* not only on this, but on any *Plane* for which 'tis made, look what a *Clock* 'tis by your *Globe*, and moving your said *Draught* on its *Plane* 'till it shows exactly the true *Hour*, do but fix it there, and you may mark out the *Points* for your fair *Lines* with all the ease imaginable.

An easier way
how to place
any paper
draught on
its Plane.

OPERATION. VIII.

How to make a Vertical or Erect Direct North Dial for the Elevation of London.

THERE is no difference between the *Fabrick* of this *Dial* and the former, unless it be in figuring it; for a *South Dial* revers'd is a *North Dial*, the *After-noon Hour Lines* being mark'd with the *Morning Figures*, and the *Morning ones* with those of the *Afternoon*; So that the *Top* of the *Stile* points now upwards, as may be seen by *Scheme* 9th, and by the upper part of *Scheme* 10th. to wit, by the *Semi Circle* P T C; therefore when you chuse a *Center* in your design'd or real *Plane* for this *Dial*, let it be in the lower part of it to have Room for the *Hour Lines* to run upwards.

And by the way you must here remember, that tho' I had you in the making of this your *Vertical South Dial*, to take the distance between the *Zenith* and the *Interfection* of the *String* with the next *Hour Circle* for the 1 and 11 a *Clock Hour Lines*, &c, yet that *Section* of your *Globe* by your *String* from the *Zenith* as aforesaid, gives in truth a *North Dial*, and therefore in strictness you ought to have taken the *Distance* between the

A Memorandum.

Nadir and the several Intersections of the *Plane* with the *Hour-Circles*; but since both *Dials* are (as I told you) alike, 'tis best always to operate thus from the *Zenith*, as being more at hand than the *Nadir*, and consequently more convenient.

Demonstration.

The *Demonstration* or reason why these *Dials* show the *Hour*, differs even at first Conception but little, and at the second not at all from that already given for the *Horizontal Dial*. By the first Conception I mean our considering these *Planes* as *Vertical* and *Erect*; for since the *Hour-lines* of all *Dials* are (as I shew'd you in the former *Demonstration*) the *Intersections* only of the respective *Hour-Circles* with the *Planes*; and since the hourly indicating *Shade*, is the *Shade* of the *Axis* or of the *Hour-Circle*, which then lies in the *Plane* of the *Sun*, it must follow, that the *Mark* made (for example sake) by the 4 a *Clock Morning Hour Circle* on the *String*, and the *Center* of the said *Plane* (which is the common passage of all the *Hour-Circles*) will be two true *Marks* or *Points* for you to draw that *hour-Line* by, and consequently that the *Shade* of the *Axis* will still fall on the said *hour-line* as often as the *Sun* comes into the *Plane* of that *Hour-Circle*. Now your *blind Circle* is (by construction) equal to the *Circle* made by the *String* on the *Globe*, and the *Marks* on its *Limb* are equal to the *Marks* on the said *String*, therefore the *Dial* must be truly drawn, and the *Stile* plac'd on the 12 a *Clock line* (to wit on the intersection of that *Hour-Circle*, which falls on the *Plane* at right *Angles*) must truly cast its *shade* from time to time, seeing by its *Site* and *Angle* it corresponds with the *Axis* of the *World*. As for our second Conception in reference to these *Dials*, we shall find by it that their *Planes* are real *Horizontal* ones to some People or other; for this *Section* of the *Globe* being a great *Circle* will be the *Horizon* to those that live in the *Pole* of it, viz. to those under our *Meridian* 90 Degrees from our *Zenith*, which being a point in our *Horizon*, makes their *Horizontal Dials* always our *Direct Vertical* ones, and their *Direct Vertical Dials* our *Horizontal* ones. 'Tis plain then, that the present *Dials* are exactly describ'd, if our former *Directions* and *Proof* of an *Horizontal* one be true; for all the *Hour Lines* are here drawn from the *Center* to the several intersections of the *Hour-Circles* and *Horizon*, which (as we are

are to suppose) the *String* represents. Nor do's the *Cock* of these *Dials* differ from the former Rules; for having the *Meridian* or 12 a *Clock* line for *Subsilar* for the former reason, and being 38 *Degrees* and a half above it it makes an Angle equal to the *Elevation* of the People, who have the said *Plane* for *Horizon*.

OPERATION IX.

To make the aforesaid North and South Dials Geometrically, for the Elevation of London.

There is no need of a *Scheme* for this *Operation*, since 'tis a *Corollary* from what we have now said; for make but an *Horizontal Dial Geometrically* (as we formerly shew'd you in *Scheme* the 6th) according to the *Complement* of the *Elevation* of your Place, and that will serve (the figuring only consider'd) for either *Dial*.

Here then you may see that OS, or ON the *Basis* or Foot of the *Stiles* of these *Dials*, (that is to say, the distance between its *Center* and its *Horizontal* edge or side) is ever the *Tangent* of the *Elevation*; for 'tis the *Tangent Complement* of FS or NR the *Stiles* height above the *Plane*. And here also you see that the very same *Dial* (the figures only transpos'd) will serve both for an *Horizontal* and this *Direct Vertical* one to those that live in the *Latitude* of 45 *Degrees*, since the *Elevation* of the *Pole* and *Complement* of it is there the same.

A Memorandum.

OPERATION X.

To describe by the Globe, Meridian Dials, or (as others call them) East or West Dials for the Elevation of London.

These *Dials* tho' *Vertical* and *Direct* (as passing thro' our *Zenith*, and facing also two *Cardinal Points* or *Quarters* of the *World*) are very different from the former, nor has any body (I believe) taught yet their *Description* by the *Globe*.

To perform therefore this *Operation*, you must by the help

Some few things to be of premis'd.

of your *String* or *Compasses* describe on your *Globe*, with Chalk (or the like matter) an *Arch* (as in *Sch. 11.*) which having its *Pole* at *K* (the *East-point*, for examples sake, of the *Aequinoctial*) cuts somewhere or other the 11 a *Clock Northern hour Circle*, I mean the 11 a *Clock hour Circle* on the *Northern*, or black part of the *Globe*; and this *Arch* by reaching from the point *C* in the *Aequinoctial Colure* (or 6 a *Clock Circle*) to *H* in the *Horizon* on the said *Northern side* of the *Globe*, will be a piece of a little *Circle* parallel to the *Meridian* containing the *Degrees* of the *Elevation of the Pole*, and cutting all the *Hour-Circles* also from 6 to 11. But if this be thought too troublesome a work, the *Globe-maker* may avoid it by putting 6 *Pricks* or *Asterisks* upon the *Globe*, where the said *Arch* and *Hour-Circles* would intersect, as may be seen in the said 11 *Scheme* at *C, O, S, T, V* and *Z*; so that if beyond *C* he adds one *prick* more, viz. at *R*, to give you from *H* the *Radius*, or 60 *Degrees* of the said *Arch*, you need nothing else.

The Constru-
tion of an
East Dial.

This being premis'd, describe on a sheet of paper (*HR*, or 60 degrees of the said *Arch* being *Radius*) a *blind Circle* as in *Sch. 12.* and drawing the *Line H h* how you please thro' *K* its *Center* to represent the *intersection* of the *Horizon*, open your *Compasses* to the said *Arch*es full extent, to wit, from *H* to *C*, and putting one foot on the *blind Circle* at *H*, and the other marking there at *C*, draw the line *PC* thro' the *Center K*, and 'twill represent the *intersection* of the *Aequinoctial Colure* (or 6 a *Clock hour Circle*) with your said *blind Circle* or *Plane*; so that if you take from off your *Globe*, the distances between the point *C*, and the several *Intersections* of the *Hour-Circles* with the said *Arch C H*, and place them on your *blind Circle* on the right hand side of *PC*, as well below the *Horizon H h*, as above it, and draw lines thro' them (viz. *O o, S s, T t, V v*, and *Z z*) you will have a compleat *East Dial* describ'd, after you have drawn 2 lines more on the left side of the said *PC*, to wit, the *Line N v* distant from it as is *O o*, and the *Line M m*, as is *S s*. As for the figuring each hour line, it must be according to the *Figures* of the corresponding *Hour-Circles* cut by the afore said *Arch C H*, and thus you will find them figured in the forementioned *Scheme 12.* which shews you too how the *Borders* or *Parallels* are drawn for the said *Figures* to lye in, as being only double

double *Lines* (equidistant at pleasure) on both sides of the *Horizon Hh*; and here also by the *blind Lines*, and by the *fair ones*, you have before your Eyes what is necessary to be express'd on your fair *Plane*, and what not.

Nor is there any difference in the *Construction* of a *West-Dial*, except it be in turning on your draught the *Hour-Lines* or *Parallels* the other way, to the end they may all point *Northwards* on their respective *Planes*; for thus (in *Sch. 11.*) do the *Prick Lines* (m 8, n 7, c 6, o 5, s 4, t 3, u 2 and z 1.) which would truly represent this *Dial*, if they were produced in the said *Scheme*.

Now for the *Substilar* 'tis the 6 a *Clock Hour Line*, since that *Hour Circle* falls on the *Plane* at right Angles, and as for the *Cock* it may be a *Gallows Stile* (as in *Scheme 13*) or a *Pin* (as in *Scheme 14*) so it be plac'd on the *Substilar* and perpendicular to it, having its height equal to the Distance between the Pricks or *Asterisks* C and P in the said 11 *Scheme*, or (which is all one) to the distance between K and X. viz. the nearest distance between the *Substilar*, and the 9 a *Clock hour line* in an *East-Dial*, and the *Substilar* and the 3 a *Clock Line* in a *West Dial*.

But here you are to remember, that when I say, that the height of the *Stile* is to be equal to the distance between C and P. I mean in rigour equal to the *Sine*, and not the *Chord* of that *Arch*; but seeing the *Chord* of 10 Degrees, differs not sensibly from the *Sine* (and by the way the *Arch* C P on the *Globe* will not be above 10 Degrees from the *Meridian*;) the interval between C and P will serve the Turn. But if you would be more exact take between your *Compasses* the distance of double C P, to wit the interval of (suppose) 20 degrees, and half of it is the required distance; for half the *Chord* of 20 Deg. is equal to the *Sine* of 10. Or if you please you may erect a needle at C Parallel to P (the elevated *Pole* of the *Globe*) and the distance between them will be the true Height of your *Stile*. To Conclude, You may contract and enlarge these *Dials* as you please, by drawing the hour-lines twice or thrice (or according to any other proportion) nearer or farther asunder, and so abateing or heightning in the like manner your *Stile*.

The *Demonstration* is obvious, for since the points M, N, C, O, S, T, V and Z in the upper part of the *blind Circle* or *Plane*, and the Points $\mu, \nu, \pi, \rho, \sigma, \tau, \varphi, \zeta$. on the lower part of it are (by being equal in distance to those on the *Arch*) the intersections of the

Of a West Dial.

Of the Stile and Substilar.

The Demonstration.

the morning *hour Circles* of 4, 5, 6, 7, 8, 9, 10, 11. with the edges of the said *Plane*, it follows that the *Lines* drawn from the corresponding *Points*, must be the true *hour lines* of this *Dial*, since the *hour Lines* (as we said) of all *Dials*, are only the *Intersections* of the respective *hour Circles* with the *Plane*. Again the *shade* of the *Axis* (the *Axis* being a part of all the *hour Circles*) falls ever on the *Hour-Line* or *Interfection* of this or that *Hour Circle*, as often as the *Sun* comes into the *Plane* of that *Hour Circle*, therefore the *Stile* of this *Dial* representing truly the *Axis* (since 'tis above the *Plane*, and distant from it as 'tis on the *Globe*) will cast its *Shade* every hour on the corresponding *hour Line*; and as for the reason, why the height of the said *Axis* is equal to the distance between the 3 or 9 a *Clock Lines* and the *Subsilar*, it shall be shown in the *Demonstration* of the next *Operation*.

OPERATION XII.

How to describe an East or West Dial Geometrically for the Elevation of London.

The Construction.

DRAW the blind *Line* *Hb* and cross it from your left hand (as in *Sch. 13.*) with *Æa* another blind-line to make an *Angle* at their *Interfection* *K* equal to the *Complement* of the *Elevation*, then pricking in the said *Line* *Æa* on the right side of *K*, the respective *Tangents* of 15. 30 45. 60. and 75 Degrees, as also on the left the *Tangents* of 15 and 30. Draw but *Perpendiculars* through the *Pricks*, and you have an *East-Dial*, whereas should you cross (as in *Sch. 14.*) *Hb* with *Æa* from the right hand, and pricking the aforesaid *Tangents* the other way, draw *Perpendiculars* through them, you would have a *West-Dial*. By these *Schemes* also you may know how each *Dial* is to be Figur'd; the *East-Dial* containing (as you see) all the hours from 4 in the morning 'till Noon: and the *West* all the hours from Noon to 8 at Night. Now for their *Sticks*, they are (as I said, in the last *Operation*) to be a *Pin*, or a *Gallowes Stile*, and in height equal to the *Tangent* of 45. Degrees, or distance between the 9 or 3 a *Clock hour Lines* and that of six, which is ever their *Subsilar*.

The Demonstration.

These *Dials* must be true, if their *Planes* lye in or Parallel to the *Meridian*; for since the *Line* *Hb*, by being plac'd according

cording to our *Hypothesis horizontal*, represents the intersection of the *Horizon*, and the line *E a* that of the *Aequator*, by making an *Angle* with the said *H b* equal to the complement of the *Elevation*, the *substilar* must be the *Intersection* of the *Aequinoctial* Circle (or 6 a *Clock* hour Circle) with the *Plane*, since that *Hour* Circle falls on the *Plane* at right *Angles*. If then a *Gallows* *Stile* be set on the said *Substilar* and Perpendicular to it, its *Shade* must needs constantly cross the *Aequator* *E a* at right *Angles*. Now when the *Sun* is in the *Plane* of the 6 a *clock* hour Circle, his *Ray* makes no *Angle* with the said *Stile*, because the *Sun*, and the *Stile* are in the same *Plane*, and so the *shade* falls directly along the *Substilar*, but when he gets (for examples sake) into the next *hour* Circle, his *Ray* (the height of the *Stile* being *Radius*) makes an *Angle* of 15 *Degrees* with the said *Stile*, and consequently the distance of the two *shades* are in the line *E a* the *Tangent* of those *Degrees*. The like therefore being said of the next *Hour* Circle and so on, it follows (as I mention'd in the beginning) that the pricking from the intersection *K*, the *Tangents* of 15, 30, 45, 60 and 75 *Degrees* in the line *E a*, must give you points to draw the perpendiculars or true *hour*-lines of this *Dial* by, as also, that the *Tangent* of 45 *Degrees* gives the height of the *Stile*, since the *Tangent* of those *Degrees*, (which you see gives the 3 and 9 a *clock* lines) is equal to the *Radius*.

Here also we see not only why these *hour*-lines are so unequally distant, since they are so many *Parallels* max-
shall'd according to the *Divisions* of a *Tangent* line, but why the
12 a *clock* hour line can never be really express'd, for 'tis the
Tangens of 90 *Degrees* which is infinite.

The reason of
the unequal
distance of
these hour-
lines.

OPERATION XIII.

How to describe a Declining Dial by the Globe for the
Elevation of London.

The first Way.

THIS *Plane* (as passing from the *Zenith* to the *Nadir*) is What a *De-*
still *Vertical*, and should (you may suppose) be by right the *clining Plane*
primary *Vertical*, but by its tendency towards the East or
West Points, its *Dial* takes the Appellation of a Declining one,

N

that

that is to say, of a *Dial*, whose *Plane* declines so many degrees from facing directly the *North* and *South*, as is its tendency towards the said *East* or *West* points.

The Constru-
tion.

* pag. 80.

To describe
the Morning
hours of a
Declining
Dial.

As for the way of making this *Dial* it differs little from the first *Direct Erect one*, already * treated of, for supposing your present given *Plane* declines 40 Degrees from full *South* towards the *East*, you must draw your *String* (which ever represents the *Edges*, as we have said, of your *Plane*) not throu' the *East Point* of the *Horizon* of your *Globe*, as before, but throu' 40 Degrees further towards the *North*, for this makes the *String* to represent part of a *Plane* that comes nearer (by so many Degrees) the facing of the *East* than it did. Then opening your *Compasses* at 60 Degrees in any of the great *Circles*, and describing (as in *Sch.* 17th.) the *blind* one *PZW*, prick in it from its *Meridian Line* *OZ*, the distance between the *Zenith* of your *Globe* and the intersection of your *String* with the first *Hour-Circle* (to wit between *Z* and *b* in *Sch.* 15.) and it will give you a mark for the 11 a *Clock* line on your *Dial*; and the distance between the *Zenith* and the Intersection of your *String* with the next *Hour-Circle* (to wit between *Z* and *c*) will give you the mark of the 10 a *Clock* line, and thus you must proceed to every *Hour-Circle* cut thus by your *String*, till it falls on the *Horizon*, that is to say from *c* to *d*, *e*, *f*, *g*, *h*, letters marking (as you see in the said *Scheme*) the 9, 8, 7, 6, 5 and 4 a *Clock Hour-Circles*, and consequently giving you those *Hour-lines* on your *Dial*.

To describe
the Afternoon
Hours.

Now for the *Afternoon hour* lines (which are no longer equal in distance to the *Morning* ones,) you have nothing to do but to draw your *String*, on the *West-side* of your *Globe*, throu' 40 Degrees in the *Horizon* the contrary way (*viz.* from the *West* towards the *South*) and the distance between the *Zenith* and the Point in the first *Hour-Circle* cut by your *String* (to wit from *Z* to *k* in *Sch.* 16.) will give you the mark for 1 a *Clock*, and the distance from thence to the next Point or Intersection gives you that of 2, to wit, from *Z* to *l*, and in this Order you are to proceed to *n*, the 4 a *Clock Hour Circle*, that is to say, till you come to the intersection of the *String* with the *Horizon* on the *West-side* of your *Globe*.

How to make
the Style and
Subsilar of a
Declining
Dial.

As for your *Style* and *Subsilar* they differ also from those of direct *North* and *South* *Dials*; for the said *Style* or *Cock* is to be no longer plac'd on the 12 a *Clock Line*, nor will its height now

be

be equal to the Complement of your Elevation, therefore having drawn your String throu' the Degrees of Declension in the *Horizon* as before, and putting one foot of your *Compasses* in the *North Pole*, find with the other the nearest Point on your String, to wit S (as in *Sec. 15.*) and the distance between S the said nearest Point and the *Zenith* of your *Globe* will be Z S in the *blind Circle* of *Scheme* the 17th, to wit the distance between the *Meridian Line* of your *Dial* and your *Subsilar*, which in this our *Example* lyes from the *Meridian* towards your left hand or *Morning hours*, and the distance from the said Point in the String to the *Pole* (being from S to P) will in the said *blind Circle* be the height of your *Stile*; so that if you erect and place your said *Stile* from the *Center* all along the *Subsilar* O S it will continually show you the *Hour*.

But if you fancy that the Extension of your *Compasses* from the *Pole* to the String will not give you precisely this Point, since your said *Compasses* may seem to touch it in several Points; I say, if you doubt or fancy this, fasten a *Thred* on the *Pole*, and drawing it streight over the *Horizon* at 40 Degrees from the *Meridian* of your *Globe* Eastwardly (i.e. till it passes throu' the *Pole* of the *Plane*) see where the said *Thred* crosses your String (or edge of the *Plane*) and there the true requir'd Point will be. The *Demonstration* of this *Dial* is in the following *Operation*.

A Memorandum.

OPERATION XIV.

How to describe by the *Globe* a *Declining Dial* for the *Elevation* of *London*.

The second way.

Draw your String over at 40 Degrees in the *Horizon* from the *East* Northwardly, and from the *West* Southwardly, as before, and the respective distances between the *Zenith* and the Intersection of your String with the *Hour-Circles* will give you in any great Circle of the *Globe* the Degrees of their respective distances as well for the *Morning* as *Afternoon*, and the proportionable Degrees in any Circle will give you the Points for the Drawing of your *Hour-lines*, as I shew'd you in the Construction of the former *Vertical North* and *South Dials*, and

The Construction.

as for the *Stile* and *Sub-stilar*, you must operate as directed in the foregoing *Operation*, that is to say, the number of *Degrees* between Z and S gives you the *Sub-stilar*, and those from P to S the height of your *Stile*.

The Demon-
stration of
these 2 decli-
ning Dials.

As for the *Demonstration* or Reason why *Dials* thus made show the Hour, it is this; First you see that the *String*, by being on one side removed 40 *Degrees* from the *East* point Northward, and on the other side 40 *Degrees* from the *West* Point Southward, represents on the *Globe* the requir'd *Plane*, and therefore wheresoever the *Hour Circles* cut it, there the *Shade* of the *Axis* will fall, as we shew'd you before in the former *Dials*; Now two Points made by the intersections of each *Hour Circle* with the *Plane* being given you (to wit, the *Center* where they all meet, and their respective marks on the *String*, or supposed Edges of your *Plane*) it must needs follow, that if you draw Lines throu' those Points, they will be true *Hour Lines*; for (as we have often said) the *Hour-Lines* of all *Dials* are only the intersections of the *Plane* with the *hour Circles*. In the next place, since P S by construction is the nearest distance from the *Pole* to your *String* or *Plane*, it appears that the *Hour-circle* which cuts the said *Plane* at S, falls on it at right Angles, and consequently that as P S (the height of the *Pole* or *Axis* above the *String* or *Plane*) gives the true height of the *Stile* of this *Dial*, so the intersection of the *Plane* with the said *Hour-Circle* must be the true *Substilar*; for the *Substilar* (as we already mention'd) is only the intersection of the *Plane* with the *Hour-Circle*, which falls at right Angles on it; Ergo The distance between Z and S gives in your *blind Circle* the distance from your 12 a Clock line to the *Substilar*, and P S the height of the *Stile*.

A Memorandum.

And by the way, here it appears not only why the 12 a Clock Lines of Declining *Dials* continue perpendicular, but also why their Centers keep the same distance from the Horizontal Edges of their Planes, as do the Centers of the primary Vertical or direct North and South *Dials*; I say, here all this appears; for the 12 a Clock Line (which is ever the intersection of your *Alexidian* with these *Planes*) being a Perpendicular in the primary Vertical *Plane*, becomes the *Axis* of the *Horizon*, and all Vertical *Dials* by their Description move only about it, so that both the Center and the said 12 a Clock Line remain the same in all; therefore the Tangent of the *Elevation*, being (as I

* formerly shew'd you,) the length of the foot of the *Stile*, or * *pag. 84.*
distance between the Center of a *Primary Vertical Dial* and its
Horizontal Edge is that of a Declining one also.

But to proceed with the *Demonstration*; you must remem- *Another De-*
ber that this *Dial* is an *Horizontal* one (as we shew'd you * be- *monstration;*
fore) to those that dwell in the *Pole* of the *Circle* describ'd by * *pag. 83.*
the *String*, i. e. to those in our *Horizon* 40 Degrees Eastward
from the *Meridian*; or (which is all one) to those that dwell
where the *Thred* cuts the *Horizon*; but all the *Hour-Lines* are
truly drawn according to the former *Rules* of an * *Horizontal* * *pag. 73.*
Dial, to wit from the Center to the *Points* where the respective
Hour Circles cut the *String* or *Limb* of the *Plane*; therefore it
must truly shew the hour.

OPERATION. XV.

How to describe Geometrically a Declining Dial for the
Elevation of London.

The first way.

THIS *Dial* being (as I said) an *Horizontal* one to those in *The constru-*
our *Horizon* 40 Degrees Eastward from the *Meridian*, *tion.*
Find (as we shew'd you in the * *Geographical* or 20 Section) what * *pag. 23.*
Elevation or *Latitude* they have, and describe Geometrically an
Horizontal Dial on paper for the said *Elevation*. In the next
place consider the difference between both *Longitudes*, to wit
how many *Hours* the *Sun* comes sooner to their *Meridian* than
yours, so that if he comes, suppose, 3 hours, 'twill follow, that the
3 a clock hour line is to be the true 12 a clock line of this *Plane*,
because 'tis really so late with those People, when 'tis but Noon
with you, and consequently that their 4 will be your 1 a clock,
and their 2 your 11. and in the like manner you are to mark the
rest, having nothing more to do but to draw on your fair *Plane*
a * *Line* Parallel to the *Horizon*, and to place on it at right An- * *pag. 2.*
gles the true 3 a Clock Line, (that is to say the 12 a clock line ac-
cording to your now alteration or present figuring the *Hour-*
Lines;) for you will have all the requisite Marks or *Points*, not
only to draw the other *Hour Lines*, but also plainly to see,
where the *Subsilar* will fall, and how high the *Cock* it self is
to be; for they are all to correspond with those in the said Ho-

izontal

Horizontal or Paper Draught. Now in case the difference of Longitude between these 2 Places happens to be a Fraction, as (suppose) one hour and 10 minutes, then (if the Declination of your Plane be still Eastward as in the former example) 10 minutes past 1 must be markt in the Horizontal Draught with the Figure 12, as the Meridian Line, and 2 and 10 min. with Figure 1, and so on all along; whereas if the Declination were Westward, then 11 and 10 minutes will be the said Meridian Line, 10 and 10 minutes your 1 a Clock Line, &c; for thus you must operate in all other Cases, that is to say, you must still allow by the new figures the difference of Longitude, that chances to be between you and them, to whom the Declining Plane is Horizontal. But because this manner of Dialling may seem to some troublesome and confus'd (especially when the said Difference of Longitude happens to be a Fraction, and not even Hours) I shall here adjoin a second Geometrical Way.

OPERATION. XVI.

How to describe Geometrically a Dial declining 40 Degrees Eastward, for the Elevation of London.

The second way.

The Construc-
tion.

HAVING made an Horizontal Dial for this Elevation in the lower part of your Paper Plane, (as 'tis express'd by the prick lines in Scheme 18) and drawn from the Center A the several Hour-Lines upward as far as you think fit, and Figur'd them to show what Hour-Lines they are, chuse in A C (the 12 a clock line) any Point, suppose P, and draw throu' it the blind Line G D making with the said A C an Angle of 30 Degrees or Complement of your Declension; then erect the Perpendicular P B on the said blind line at P, and taking with your Compasses (AP being your Radius) the Tangent of 51 Degrees and 3, or true Elevation of the Pole, put one foot on P, and where the other marks on the said Perpendicular (suppose at F) there will be the Center of your Declining Dial; so that having bordred your Plane with fitting Parallels, to contain the standing Figures of each hour, you have nothing more to do, but

but to draw fair Lines from the said Center F, to your Border, thro' the Intersections of the Line G D with the several Hour-lines of the *Horizontal Dial*; that is to say, you have nothing more to do, but to draw fair Lines thro' the Points KLMNO PQR which give the hours of 7, 8, 9, 10, 11, 12, 1 and 2; and by the way you may have as many other Morning or Evening hours as you please: if you draw the said G D long enough for the other hour-lines of the *Horizontal* to meet with it. Nor is there more difficulty here about the *Stile* and *Substilar* than in any of the former *Dials*; for (A P being Radius) 'tis but taking the *Sine* of 40 Degrees (or Declination of the Plane) with your *Compasses* from the *Sector*, and putting one foot on your 12 a clock Line at P, the other foot will in the line G D (to wit, at M) give you the Point for to draw the *Substilar* FM, and the *Sine Complement* of the Declension, or *Sine* of 50 Degrees, will be X M the *Stiles* height. Nay, if (for want of a *Sector* or the like) you cannot conveniently find the *Sine* of the said Declension, do but observe where a *Perpendicular* from A falls on G D suppose at M, and P M will be the distance in the said G D between the 12 a Clock line of this *Dial* and its *Substilar*, and AM (equal to X M) the height of the *Stile* above it. Thus then we see that the *Fabrique* of a *Declining Dial* (which is wont to terrify young Students) is in a manner as quick and easy as that of the *Horizontal*, since two ordinary Lines more, viz. G D and B P give us all the Points necessary for its Description.

A ready way
to find the
Stile and Sub-
stile of a de-
clining Dial.

The *Demonstration* and Reason of this *Dial* is evident; for, the *Horizontal* being by construction true, any *Erect Plane* facing the South, that crosses its *Meridian* (or 12 a clock line AC) at right Angle: will represent a *Primary Vertical* or *Direct South Plane*, and then the Center of the *Dial* described on it will be distant from P the intersection of the two *Planes* on the said A C) the *Tangent of the Elevation*, as I shew'd you * before. * pag. 92. Now, since G D is (by Hypothesis) the Edge of a *Vertical Declining Plane*, and since (as we shew'd you in the before cited place) that the 12 a Clock line, as well in a *Declining* as in a *Primary Vertical Dial*, is *Perpendicular* to the *Horizon*, containing in it the Centers of the said *Dials*, it follows that F P (being the *Tangent* of the *Elevation*, and *Perpendicular* also to the said D G where it cuts the 12 a Clock line of the *Horizontal*) must be the 12 a Clock line, and F the Center of our present *Dial*,

The Demon-
stration of the
Stile and Sub-
stilar.

Dial, whose Declension is 40 Degrees Eastward, since F P declines so many Degrees from CP toward the morning Hours, for the said CP and FP represent the 12 a Clock lines of a Direct, and of our thus Declining Vertical Plane, if you consider them flatted down, and lying in the *Horizon*. This being so, 'tis evident that the Lines drawn from F to K L M N, &c. are the true *Hour lines* of our *Dial*, as falling from its Center to the several Points made on its *Horizontal edge*, by the *Hour Circles* or (which is all one) by their Intersections with the *Horizontal Dial*. As for the *Stile* and *Substilar*, let us but consider the Triangle AMP, and we shall find that P is by construction the Angle of 50 Degrees, and A that of 40, as subtended by the Sine of the Declension, so that A being a right Angle, AM must be a perpendicular; therefore the *Hour Circle*, whose intersection the said AM happens to be, falls at right Angles on our present Plane, and consequently gives the *Substilar*; Now since the *Axis* of the *World* passes through F and A, the Centers of the two *Dials*, when they are joyned (as we now suppose them) at G D the common Section of their Planes, I say, since the *Axis* passes throu' their Centers, its Elevation or Height above our Plane must be AM, as being the only Perpendicular that can fall from it upon the said Plane, and consequently its Measure, but A M you see is the Sine Complement of 40, since PM is the Sine of 40, Therefore in all Declining Dials, The Sine of the Declension (from their 12 a Clock Line) gives in their *Horizontal Edge* their *Substilar*, and the Sine Complement their *Stile*. Q. E. D.

OPERATION XVII.

To take the Declension of a Plane.

Compose your Globe and find exactly the *Azimuth*, i.e. what Degree of the *Horizon* is cut by the String's shade, when it passes throu' the *Zenith* and *Nadir*, which we'll suppose to be the 50th from the South towards the West; then having slipped out (to an equal length) the two Rulers from under your *Pedestal*, Hold your *Globe* level, and apply the said Rulers, as soon as you can, to your Plane, (as you did when you drew an *Horizontal Line*) and find again the *Azimuth*, which now being (for example;

ample) 90 Degrees shows your *Plane* declines 40 towards the East, because, the *Azimuth* being now increas'd so many Degrees, the *Meridian* (which by the help of the said *Rulers* was perpendicular to your *Wall or Plane*) is turned thereby from true *South* (as formerly it stood) towards the *East* the above-mentioned number of 90 Degrees; but had the *shade* fallen on the 10th. Degree, your *Plane* would (for the same Reason) have declin'd 40 Degrees towards the *West*. In short therefore, the difference of these two *Azimuths* is the thing that resolves the Question; for when they are equal there is no *Declension* at all.

Of Reclining Dials.

THE *Horizontal Plane* lay open (we saw) to the whole *Hemisphere*, whilst each *Vertical one* enjoy'd but half of it; for, by being *Vertical*, a moiety of the said *Hemisphere* is before, and the other behind it. Now the *Reclining Plane* (which is express'd by *Sch. 29.*) instead of being perpendicular to the *Horizon* bends towards it, yet so, that its bending has nothing in it of overwhelming or tendency towards those, that behold it (as it happens to *Inclining Planes* express'd by * *Scheme 30.*) but still exceeds, according to the Degrees of its *Reclination*, farther and farther from them, making thereby an *obtuse Angle* with the *Horizon*, and consequently faces more than half the apparent Heavens, as the *Inclining one* does less, whose *Angle* is therefore ever *Acute*. * *vid. pag. 104.*

As for the kinds of *Reclining Planes*, there are (I may say) 4, to wit, the *Aequinoctial*, the *Polar*, the *Direct Reclining*, and the *Declining Reclining Plane*; for each of these appropriates to it self a particular *Fabric*, or way of making, and therefore we will Treat of them in Order. * *vid. pag. 105.*

OPERATION XVIII.

How to describe a Dial on an *Aequinoctial Plane*, both by the *Globe*, and *Geometrically also*.

THIS *Plane* is represented by the *Globe*, when 'tis Compos'd The Construc-
and cut (as in *Scheme 20.*) quite thro' at the *Aequino-* tion and De-
thid, therefore open your *Compasses* at 60 Degrees there; and monstration.
O de-

describing the *Blind Circle* ABCD in *Schema 21*, divide it as the *Hour-Circles* cut the said *Equinoctial* (in *Sch. 19th*) that is to say, divide it into 24 equal Divisions, and there will rest nothing more to be done, but to draw Lines from the Center O, through as many of those Divisions as you shall think necessary, and then to Figure them successively from *Morning* to *Night*. As for the *Stile* (seeing the *Axis* of the *World* is at right Angles with any *Diameter* of the *Equator*, and runs throu' the Center of it) it must needs follow that the *Perpendicular Pin* O P plac'd in the Center of your *Dial*, will perform that Office; for when it directly points to the *Pole* it represents the said *Axis*, as the divided *blind Circle* does the *Equinoctial*, and its Divisions; therefore since the *Shade* of the *Axis* ever falls (according to the time of the Day) on *This* or *That* intersection of the *Hour-Circles* with the *Equator*, the *Shade* of the *Pin* must fall also on the corresponding *Hour-line* of the *Dial*, as being (in the effect) the same thing, in case the 12 a *Clock Line* be plac'd on a *Meridian line*, and mounted at A (its *South side*) above the *Horizon*, the *Complement* of the *Elevation* of the *Pole*, i. e. 38 Degrees and a half for by this means your *Plane*, from an *Horizontal* one, will be perfectly that of the *Equator*.

How to make
an Horizontal
Plane an
Equinoctial
one.

The Demon-
stration.

Nor is it hard to mount thus the said *South side* of your *Dial*, since 'tis but opening your *Compasses*, in any great Circle of your *Globe* at twice as many Degrees as is the *Complement* of the *Elevation*, to wit 77 Deg. and they will give you the true length of a *Perpendicular* to underprop withal the aforesaid A, or *Southern point* of the 12 a *clock line* of your *Dial*. And the reason of it is, because AC the *Diameter* of your *Dial* being (by *Hypothesis*) equal to the *Diameter* of the *Globe*, becomes now (C being Center of the new *Arch*, made by the mounting or raising the side of your *Plane* above the *Horizon*) a *Radius* double to OA the former *Radius*. Therefore since the *Chord* of a double *Arch* is ever the *Sine* of the single *Arch* in a *Circle*, whose *Radius* is double the other, it follows that the *Chord* of 77 Degrees is (in respect to the double *Radius* AC) the *Sine* of 38½, 30 m. and consequently will perform (if erected *Perpendicularly*) the design'd *Operation*.

The Geometrical
Construction.

Now for the *Geometrical Construction* of this *Dial*; (since it consists only in dividing a *Circle* into 24 equal parts) with a

perpendicular *Cock* or *Stile*,) there is no need of more words about it; so that we'll end here with a *Memorandum*, viz. that as the *Reclining* face of this *Plane*, shews the Hour from *Spring* to *Autumn*, so the *Inclining* Face, or other side of it does the same, for the remaining half year, to wit, from *Autumn* to the *Spring*.

A Memorandum.

OPERATION XIX.

How to describe a Polar Dial, both by the Globe, and Geometrically also.

THE true *Plane* of this *Dial* is speculatively the *Plane* of the *Equinoctial Colure* or 6 a *Clock Hour-Circle*, but in practice that of any *Circle* parallel to it, so that the *Construction* and *Demonstration* of a *Dial* on it, is (*mutatis mutandis*) the same with that on a *Meridian Plane*, of which we have already so fully * treated.

* pag. 8.

Make then by your *Globe* (for example sake) an *East Dial* on a *Meridian Plane*, according to any of the former ways, and if you alter but the *Figures*, that is to say, if having figur'd the *Subsilar* instead of 6 with 12, you mark the Morning 7 a *Clock Hour* line of the said *East Dial* with 1, that of 5 with 11, and so on in Order, it will be a true *Polar Dial*, showing you exactly the Hour, when it directly faces the *South*, and *Reclines* so, that the *Apex* or uppermost part of the *Subsilar* or 12 a *Clock* line points just to the *North Pole*; for then the back-part of the *Plane* makes an *Angle* with the *Horizon* equal to that of our *Elevation*.

The Construction.

This *Operation* may be also perform'd of it self without the former consideration, since 'tis but putting one foot of your *Compasses* on the Interfection of your *Meridian* or 12 a *Clock* hour Circle with the *Equator* of your *Globe* (to wit, on K in *Scheme* 22) and so describing with Chalk the *Arch* CÆ, I mean an *Arch* which reaching from the said *Meridian*, cuts the Morning 7 a *Clock*, or if (you please) the Evening 5 a *Clock* Hour Circle somewhere or other; for then if you draw a *blind Circle* (as in *Sch.* 23.) of the same bigness, and take the several

ral distances between the Pricks or intersections of the *Hour-Circles* with the said *Arch*, to wit, the distances between C and O, C and S, &c. and place them on the *blind circle*, on both sides of P C K π the *Subtilar* or 12 a *clock line*, as well below the line $\text{Æ} \text{æ}$, as about it) the lines drawn from the said Pricks will be true *Hour lines*, and the distance between C and P or between K and X will (for the reasons mentioned in the *Description of the Meridian Dials*) be the height of the *Stile*.

Now to describe this *Dial Geometrically*, 'tis yet more easily performed, for if you draw (as in *Scheme 24.*) the Line A B parallel to the *Horizon*, and then take a Point in the middle of it (suppose K) do but prick on both sides of it the *Tangent* of 15, 30, 45, 60, and 75, and the several *Perpendiculars* drawn throu these Pricks will be true *Hour-lines*, which you may figure as you see in the before mention'd 24th *Scheme*, and as for the *Stile* the *Tangent* of 45, (or distance between the 12 a *clock line*, and that of 9 or 3) gives you its height, which is to be a *Pin* or *Gallowas Stile* as before, and the 12 a *clock line* the *Subtilar*.

OPERATION XX.

How to describe a Direct reclining North or South Dial.

The Constru-
tion and De-
monstration
of a declining
direct Dial
facing the
South.

SUPPOSE then that the *Plane* lay directly *South*, and that its *Reclination* were 20 *Degrees*, you have nothing to do, but either *Geometrically* to make on it a *direct Vertical South Dial* for the *Elevation* of 71 *Degrees* and $\frac{1}{2}$ (I mean for a *Plane* 20 *Degrees* nearer the *Pole* than your own *Zenith*) or to fix your *String* on 71 gr. and 30 min. in your *Meridian* (that is to say at A in *scheme 25th.* and then to draw your said *string* over the *East* or *West* Points of your *Globe*, for 'twill represent this *Plane*, since it *Reclines* or falls back from the *Zenith* 20 *degrees*; therefore the *Distances* between the *Hour-Circles* that intersect with your *String*, must (for the former reasons) give you in any *blind Circle* (which shall be equal to a great one on your *Globe*) marks (*viz.* b, c, d, e, f, g,) for the corresponding *Hour-lines*; and the *Meridian* being the *Subtilar* (since 'tis

the

the *Hour Circle* that falls on the *Plane* at *right Angles*) the *Height* of your *Stile* must (as in all *Direct Vertical Dials*) be the distance from the *Pole* to A, the supposed Point, or Place where your *String* is fixed. Now had your *Plane* Reclin'd 20 Degrees the other way, that is to say, had it Reclin'd so many Degrees facing the *North*, you must have fixed your *String* at N, viz. 20 Degrees short of the *Zenith*, and consequently your said *String* would have intersected with the *Hour Circles* at o, p, q, r, s; therefore a *Direct Vertical North Dial* for the Latitude of 31 g. 30 m. will be the required *Dial*.

A Direct North reclining Plane.

OPERATION. XXI.

How to make a Declining Reclining Dial by the Globe.

Suppose your *Plane* declin'd 40 Degrees Eastward (as did the late Declining * Vertical) and then Reclin'd 20 Degrees with a Southern Aspect, and by the way you must remember, that I mean in general by a *Planes Reclining with a Southern Aspect*, its looking towards that Quarter, tho' it be turned more or less from *Direct South* towards the *East* or *West*; in like manner a *Declining Reclining Plane* with a *Northern Aspect* turns from *direct North* towards one of the aforesaid Points. Supposing then a *Plane* thus *Reclining*, Do but describe or place it on your *Globe*, and your *Operation* will be as easy as any of the former.

First mount your *Bead* 71 Degrees and half above the *Horizon*, that is to say fix it to 20 Degrees from the *Zenith* of the *Globe*; then seeing your *Plane* has a *Southern Aspect*, (and so lies beyond your said *Zenith* Northward) move your *String* till it cuts in the *Horizon* 40 Degrees Westward from the *Northern Meridian*, or back part of the 12 a *Clock Hour Circle*. In the next place take a *Thread* and tying it about your *Globe* so, that it lies not only on your *Bead*, but crosses also the *Horizon* at 40 Degrees from the *East point* Northward, and 40 Degrees from the *West Point* Southward, the said *Thread* will represent your *Plane Reclining and Declining*, as aforesaid. Or, in short fix, a small *Needle* in the Point where the *Bead* lies (which we suppose at A in *Sch. 26.*) and fastning to it a *Thread* or part of the

How to describe the Plane of this Reclining Dial on the Globe.

the string, draw it over the *Horizon* at 40 Degrees from the *East-Point Northwards*, and it will give you the *Eastern or Morning side* of your *Plane*, as it will the *Western or Afternoon side*, if you draw it (as in Scheme 27.) over 40 Degrees of the *Horizon* from the *West-Point Southwards*.

The Constru-
tion.

This being done, describe a *blind Circle* or *Semi-Circle* equal to a great one on your *Globe*, for Example sake, the *blind Semi-Circle* A. T. C, and drawing from (O) the *Center* the *blind Line* O A perpendicular to the *Horizontal line* H b, take the distance with your *Compasses* between A the station of your *Needle* or *Bead*, and the point in the 12 a clock hour *Circle* cross'd by the *Thred* or *Edge* of your *Plane*, and this distance from A in your *blind Circle*, gives you there towards your left hand the Point *k*, to which if you draw a *fair Line* from the *Center* it will be the 12 a clock *Line* of your *Dial*, and the distance from the said station of your *Bead* or *Needle* to the intersection of the *Thred* with the next *Hour-Circle* will give you *l*, the mark of the 11 a clock *Line*; and in this manner you must run over all other intersections of your *Thred* and *Hour-Circles* to the very *Horizon* on both sides of the *Globe* (I mean on the *Morning* and *Evening* side of it, represented by Scheme 26 and 27) and placing their distances on your *blind Circle*, on both sides of the aforesaid O I, do but draw lines to them from the *Center*, and your *Dial* is describ'd.

A Memoran-
dum.

And here you must observe that I have (in Scheme 26. or *Eastern Face* of the *Globe*) plac'd A (the Station of the *Bead* or *Needle*) above the *Meridian*, since its true place cannot be express'd, for it ought to have bin on the other side of it, I mean on the *Western side*, which Scheme 27 is supposed to represent.

Of the *Stile*
and *Subsilar*

Now for the *Stile* and *Subsilar* there is no difference from the *Rules* of the *Declining Vertical*, since 'tis but finding the nearest point on your *Thred* to the *Pole* by your *Compasses*; for the distance between the said Point on your *Thred* and it's intersection with the 12 a clock *Hour-Circle* is the distance in the *blind Circle* between, *k* and *M* for the *Subsilar* and the distance between the said nearest Point and the *Pole*, gives *M X* the height of the *Stile* above the *Plane*. Nay, if you measure the Distance between each Point and A in any great *Circle*, 'twill give you the Degrees or Distances between A and your *Stile*, *Subsilar*, and each *Hour-line*, and consequently performs the

the second way (as we have all along mention'd) of describing
Dials by the Globe.

As for the Demonstration of this Dial, what we have formerly said about the rest proves it also; for supposing that the Thread represents truly your Plane, and that the Hour lines of a Dial, are (as I have show'd you all along) the several intersections of the Hour-Circles with the Plane, this Dial must be true, since all the Lines on it are the said intersections, as drawn from its Center to the Points made by the Hour-Circles on its Edges: Nor can there be any error in the Substilar or Stile, the first being the intersection of the Plane with it's true Meridian of the Plane, I mean with that Hour Circle which falls on it at right Angles, and the other being the real Height (as you see) of the Pole above the Plane, ergo, the whole must be true.

Another Demonstration:

OPERATION XXII.

How to describe by the Globe a Dial Declining and Reclining as the former, with a Northward Aspect.

There is no need here of a Scheme, the Construction of this Dial being in a manner the same as the former, only now you must draw your String and Bead (fitted to the Reclination) the contrary way, that is to say, over the South or forepart of the Globe throu' the 40th Degree in the Horizon East-ward from the Meridian or 12 a clock hour circle, then fixing a Needle (as *I show'd you) on your Globe, or else tying a thread round it so, that it crosses still your Bead, and the aforesaid two Points in the Horizon, you have there the Plane represented, and may consequently (by the help of the former Instructions) describe this Dial, whose Stile is to point upward, because of its Northern Aspect. * pag. 20

OPERATION XXIII.

How to describe all Inclining Dials, whether Direct or Declining.

AN Inclining Dial (of what sort soever it be) is the back or hinder part of a Reclining one of the contrary Aspect so that its hour-lines must be mark with the opposite Figures, and the

the *Stile* must point the other way; therefore if you desire a *Dial* Declining East-ward 40 Degrees, and Inclining 20 with a Southern Aspect, describe only the last *Dial*, (which has, you see, the same Declination and Reclination with a Northern Aspect) and then if you mark the Morning hour lines with the Evening Figures, and place the Paper draught the contrary way, that is to say, let the *Apex* of the *Stile* point downwards, you will perform the Operation.

As for the Geometrical Description of Reclining or Inclining *Dials* since 'tis very intricate, I shall not now trouble you with it, especially having already show'd you so facil a way by the *Globe*.

OPERATION. XXIV.

How to find the Degrees of the Reclination or Inclination of any Plane by the Globe.

First way.
* pag. 4.

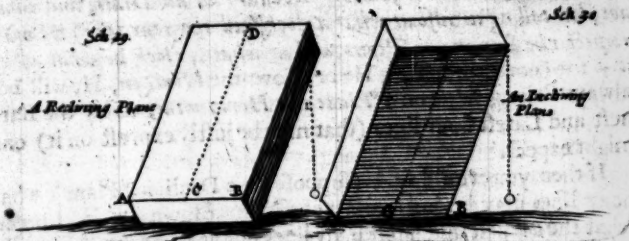
There are two ways to perform this Operation; for first (as I show'd you in taking the * *Level* of a *Plane*;) the *String* rests just on the *Horizon* of the *Globe*, when it stands on an *Horizontal Plane*, or one 90 Degrees from being *Erect* and *Vertical*.

* pag. 4.

Draw therefore on the *Reclining Face* or side of the *Plane* (represented by *Scheme 29.*) a *Line* parallel to the *Horizon* (suppose *AB*) and let fall the *Perpendicular* *CD*, then place the *Notches* of the *Pedestal* of the *Globe* (mark't with *SN*) on the said *Perpendicular*, and consider what *Degree* in the *Meridian* (counting from the *Zenith*) the *String* just lyes or rests upon, and that will be as well the *Inclination*, if the *Plane* inclines, as the *Reclination* if it reclines; for the *Complement* of this (I mean the distance between the *Point*, or Resting place of the *String* and the *Horizon*) showing always how much the *Plane* want's of being * *Level* or *Horizontal*, the *Degrees* from the *Zenith*, must needs show how much it wants of being *Erect* or *Vertical*.

As

As for the second way, Draw a *Perpendicular* on the *Recli-* The second
ing side of your *Plane*; as I now shew'd you, and placing on it $\varphi 47$.
 (after the same manner) the Notches of the *Pedestal*, expect
 'till the *Shade* of the *Pin* in the *Zenith* falls upon the *Meridian*
 of your *Globe*; for this shew's the *Sun* to be at that moment in
 the *Plane* of the said *Meridian*; then observing on what *Degree*
 of it the *Shade* of *Extuberancy* falls, place but your *Globe Level*
 or *Horizontal* with your *Meridian* in the *Plane* of the *Sun* as be-
 fore, and as the difference of these *Degrees* shows how much
 your *Plane* wants of being *Horizontal*, so that the *Complement*
 shew's what it wants of being *Erect*, and consequently the value
 of it's *Reclination* if it *reclines*, or *Inclination* if it *in-*
clines.



You may also if you please draw your *Perpendicular* on the
Inclining side of your *Plane* (as in Scheme 30th) but then the
 requir'd *Inclination*, if it *inclines*, or *Reclination* if it *reclines*,
 will be the difference in *Degrees* between the afore said shades
 of *Extuberancy*, after you cast away 90; for by how much
 the *Inclination* happens to be, by so much the shade of *Extuber-*
rancy exceed's 90, since 90 is the difference between an *Hori-*
zontal, and an *Erect* *Plane*.

OPERATION XXV.

How to find how long the Sun can possibly shine on a Plane, as also (from time to time) when we may expect him after his Rising to come on, or before his Setting to go off the said Plane.

I Defer'd this Operation till we had treated of all *Planes*, because the applying of it would then be better understood. 'Tis (tho' obvious and easy, of great Use) as not only showing us what *Hour lines* are absolutely necessary on all *Dials*, and what not, but telling us also at what a clock (all the year long) we may expect the Sun on our *Plane*, and at what a clock he must go off it; for (notwithstanding He be above the *Horizon*, He will not always so long shine on a *Plane* not *Horizontal*, as by the Earliest and Latest hour lines (that may be justly express'd on it) one might expect.

The first part
of the Operation.

If then you would find (suppose on a Declining Plane) what hour lines may be justly and necessarily drawn on it, I mean what the earliest and latest hour lines ought to be, you are only to draw your *String* from the *Zenith* (according to the Declension) on both sides of the *Meridian* (or 12 a clock hour circle) to the very *Horizon*; that is to say, you must operate in the same manner as you do, when you describe the Plane in the Fabric of this kind of *Dial*; for the Hour circles cut by your said *String* in the *Horizon* show you exactly how early he can come on, and how late he can stay on it; so that to express further Lines were needless. This then makes you stop at 4 in the Afternoon in your late * Example, where the Plane declines 40 Degrees Eastward, whereas had it declin'd but 20 your earliest hour (as you may see if you try) would have bin five in the Morning, and the latest five at Night. In short, describe your Plane (let it be what it will) on your *Globe* with your *String*, and your Hour circles, (as we said) that intersect with it in the *Horizon* answer the Question, since it clearly appear's (your *String* ever representing the Edges of the Plane) that if the Sun lyes Easterly in the Morning, and Westerly in the Evening

* pag. 89.

of the Hour-circles, that meet your String in the Horizon, He must be behind your Plane; therefore since he is not then able (tho' up) to shine upon it, 'twere needless (as we said) to express more Hour lines.

'Tis the Describing also of the Plane with your String that brings us to the knowledge of the second part of this Operation, I mean the knowing at all times when the Sun comes on, and goes off any Plane; for having describ'd one (Declining, v.g. 20 Degrees Eastward) do but observe what Diurnal Parallels and Hour-circles intersect on the Edges of your Plane, and you have your Intent; for you will by this means see, that, (tho' the Sun rises (for example sake) on the 11 of June before 4) the first hour circle, which intersects with this Parallel on the Edges of the Plane, is that of a Quarter before six, whereas about the beginning of May, he is there at half an hour past five, and on the 10 of April at or near 5. Now if you consider in the same manner the West-side of the Globe, you will see from time to time at what hour he goes off it, and thus you may do, let the Plane be what it will.

Here therefore it evidently appears, if you should erect at a-Why every En-ny time (suppose about the 10th of April) a Perpendicular stile or on an Horizontal Plane, and draw every Hour a Line along the Shade of the said stile, why such a Dial will be false, as only tel-ling you the true Hour twice in the year, to wit on the 10th of April, and about the 10th of August, viz. on the days on which the Sun run's in the same Diurnal Parallel; I say, all this now evidently appears, since every Line thus drawn on an Horizontal Plane (except the Meridian, or 12 a clock line) is no Hour line but an Azimuthal Section; I mean the Section of the said Plane, with a Circle that then passes over your head throu' the body of the Sun; so that if one of these Lines should Bear (suppose) almost S E, and be figur'd with 10 in the morning; Draw but your String from the Zenith, over that Bearing, or Point of the Compass in the Horizon of your Globe, and it will truly represent the said shade or Line on your Plane; for it show's it to be 10 of the Clock on the Parallel belonging to the said 10th of April: But since your String cuts also on your Globe (v.g.) the Tropic of ν at a little before 9, and the Tropic of ϕ at almost half an hour past 10, you may conclude that this will be the true time of the Day on the 11 of December, and 11 of June,

tho' the *shade* of the *Perpendicular stile* still show's 10 a clock at the aforesaid *Bearing*, let the *Season* of the year be what it will; therefore a *Dial* thus made must be false.

of several ingenious and humerous Dials.

HAVING thus run throu' all *Planes*, I shall at present show you how to make use of the former *Principles*, as to the ready Describing of several *ingenious* and *humerous* *Dials*, for all are now in a manner but *Corollaries* from what we have already said, and consequently easy both in *Speculation* and *Practice*.

OPERATION XXV

How to make a Dial on any Plane whose stile shall be an Arrow fixt casually on it.

The Construc-
tion:
* pag. 89.

EXAMINE what the *Plane* is, and having found it to be, suppose, a *Vertical one Declining 40 Degrees East-ward*, describe by your former *Rules*: such a *Dial* on *Paper* with the *Paper stile* F x, M. (as in *Scheme 31.*) exactly set, and mounted, then draw on the *Plane* an *Horizontal Line* H h, and place on it your said *Paper draught* so, that the 12 a clock *Line* F P, may fall at right *Angles* on the said *Horizontal line*. Lastly, move your *Draught* along it, till some part of F x or *Indicating side* of the *stile*, (suppose the Point A) just touches the *Top* or most prominent Part of the *Arrow*, and fixing there the said *Draught*, if you draw fair *Lines* on your *Plane* under those on the *Paper*, the said *Arrow* will always show you the *Hour* with its *Top*.

The Demon-
stration.

* pag. 94.

The Reason is plain: for you see by the said *Top's* just touching the *Edge*, or *Indicating side* of the *Paper stile*, it has the effect of the *Top* of A B, I mean the *Top* of a *Perpendicular* falling from the said side on the *Sub-stile*, so that X the *Top* of X M (both in the present *Scheme* and also in *Scheme* * 18. or Example of a *Declining Plane*) has this Effect also. Now since the *Top* of A B or X M, or of any other *Perpendicular*, that falls from

from the *Indicating* side *X F* on the *substile* *F M* will perform the Office of the *stile* (as we shew'd you at large in *Demonstration* of the * first *Horizontal Dial* or first Example,) it must * necessarily follow, that *A* the *Arrow's Top* do's the like. pag. 75.

OPERATION XXVII.

How to make a Dial to show the Hour without a stile on any Plane.

DESCRIBE (as in Scheme 32.) a *Dial* on *P* the given *Plane*, and erect for the present a true *stile* (as *F A B*) of *Paper* or the like, then fixing a *Glass* or any other transparent matter (suppose *G*) at what distance you please, before the said given *Plane* and *Parallel* to it, mark where *A* the *Top* of the *Stile* just touches the said *Glass*; and if there you paint a little *Asterisk* or *spot*, it will (as often as the *Sun* shines) describe such another *Figure* (at suppose *D*) by its *shade* on the said *Plane P*, and move also from *Hour Line* to *Hour Line*, according to the true time of the day.

The reason of this is also Evident; for, if *A* the top of the real *Demonstration* *Stile* show's the *Hour* by casting a *Shade* (as we shew'd you all along) on the *Hour Lines*, then the *Asterisk* being there painted where the said *Top* touches the *Glass*, must do the like; for it is, you see, the *Stile's Apex* or *Top*, and consequently casts a true *shade* to know the *Hour* by.

This *Dial* serves not only for all *double Windows*, or for *Cave* The Advan-
 ties that have over them any *Glass* or *Transparent matter*, but tage or use
of this Dial.
 shows us how to make one for any *Plane*, that is illuminated by
 a *Ray* coming throu' a *Hole*, since if you describe the *Planes* pro-
 per *Dial* on *Paper*, and move it duly (as before) on the said
Plane, till the *Stile*, or (if that be too short) till a *Thred* drawn
 along its *Indicating* side, touches the *Hole*, it will give you
 marks for the drawing the fair and standing *Hour-lines* of your
Plane, which the said *Ray* will daily run over in order, and
 consequently show you from time to time the *Hour*; for the *Ray*
 passing (as you see) throu' the *Hole* (v.g.) at *A*, and falling on the
 true *Hour Line* at *D*, performs what *A*, the *Apex* of the true
Stile (*F A B*) would do.

OPE-

OPERATION XXVIII.

How to describe a Dial, having a Picture of a Man in it, that shall Point to the Hour from time to time with his Finger.

THIS Dial is on several Planes of Mr. Lines his forementioned Pile in Whitehall Garden; and as no Dial can be more useful, so perchance none ever struck the Fancy, both of the Ignorant and Learned, with a more sudden Admiration than this, as I have often found by Experience, both in England, and elsewhere. Nor truly can it but surprize one at first to think, that a Picture (without a Machine or Movement) should have his Finger ever on the Hour, and as duly attend the Sun's motion, as if he were alive; I say, this cannot but surprize one, and yet this very Dial is as easy to be made, as any of the former.

The Construction.

Suppose then (as in Scheme 33) that the Plane given you were that of the Vertical Cavity, *a b c d*, lying directly South, describe therefore on the Glass (*A B C D*) the contrary Dial, i. e. a Direct North Dial, with a Paper Style truly mounted; and placing the said Glass over the Plane, and Parallel to it, see where the Style just touches the said Plane, and at that point (suppose *E*) let the top of the Pictures Finger be painted; then throwing away your Paper Style, and now (by the Help of a handsome Frame or the like) fixing there your Glass, all its painted Hour Lines (by hindring the Sun's Passage or Light) will project so many Dark Lines on your Plane, whilst the then true one falls directly on the Mans Finger, and consequently shows you what a Clock it is.

Demonstration.

For if there were a Hole that passed at *E* (the Top of the Mans Fingers) throu' the Center of the World to our Antipodes, it necessary follows (by the Reasons in our former Operation) that at 10 of the Clock, (suppose) at night, the Sun (being then Northward) must cast its Rays throu' the said Hole or top of the Finger, on the 10 a Clock Line of this North Dial on the Glass; but since at 10 a Clock in the morning, the Sun is in the same Plane as he was at 10 at night (only his Station is contrary)

ry) therefore he must now cast the *Shade* of the Hour Line the contrary way, i. e. on the *Mans Finger*; for, in the day time the *Hour-line* is between the *Sun* and the *Finger*, whereas in the night time the *Finger* or *Hole* is between him and the *Hour-Line*.

This *Dial* needs not always be made on a *Glass*, for 'tis sufficient if you raise a thin *Frame* (*a a a a* in *Scheme 34.*) on the Pillars *b b b b*, above *P* your *Plane*, as high as the *Glasse's* true Station or Place, for then you may cross the said *Frame* with small *Springs* or *Wyars*, which will by their interposition cast the same *shade* as the *Hour-lines* of the *Glass* would have done; so that if the *Figures* belonging to the said *Lines* be put on the *Frame*, at the end of each corresponding *Wyar*, and then pierc'd, the *Sun Beams* passing throu' their *Cavities*, will distinguish each very perfectly on the *Plane*.

Another Dial
of the same
nature.

Tho I have not time to show you all the particulars of this Learned Man's rare Invention in Dialling; (for most of the *Dials* on the aforesaid *Pile* may be naturally and expeditely describ'd by the help of this *Globe*) yet I will give you two more, viz. the two following ones, because, besides their prettiness, we may have use of them, as you shall see by and by.

OPERATION XXIX.

To make a *Dial* by which a *Blind man* may constantly know the *Hour*.

YOU must first get made in *Brass* the *Armillary Hemisphere* *ABCD E* (as in *Scheme 35*) 8 Inches, suppose in *Diameter*, representing your *Globe* cut throu' the *Horizon*; but the said *Hemisphere* is not to have any thing solid remaining, besides the *Horizon* *A B C E* with the Pieces of the *Hour Circles* (1 2 3 4, &c) that reach to it from the *Nadir*, or rather from the *Tropic of Capricorn* *AFC* on the *Northern side*, for the *Southerly Circles* are superfluous. Then having plac'd the said *Hemisphere* directly *North* and *South*, as your *Globe* stands when Compos'd, fix *G* a *Glass Bowl* of clear water 4 Inches in *Diameter* (i.e. half the former) in the midst or center of it; for the *Sun's Beames* passing throu' the Water will contract in a Point,

The construction.

The Demon-
stration.

Point, and ever burn at (suppose H) the true Hour-Circle; so that if a *Blind-man* puts but his Hand on the said *Brazen Hour Circles*, he will soon find by the Heat where the *Sun* marks, and consequently tell you the Hour; for he may easily feel how far it is from the middlemost Hour Circle, I mean the 12 a Clock Circle or Meridian. As for the Reason of this Operation, 'tis presently conceiv'd; for when the *Sun* is over against (suppose) the 5 a Clock Hour Circle on the South-side of the Dial, he must needs be over against the same Hour on the North-side, both hours making but one Circle; Now since the Center of the Bowl (by being in the Center of the Hemisphere) is in the Plane of all the Hour Circles, and since (according to the nature of Refraction) all Parallel Rays of the *Sun*, passing throu' a Sphere of Water, are (where they meet with the Direct Ray, that passes throu' the said Center) contracted into a point, viz. on the opposite side, at the distance of half its Diameter, or two Inches according to our present Example; I say, seeing this, it must needs follow, that at 5 of the Clock, the *Sun* will burn on the corresponding Hour-Circle, and if so, then a *Blind-man* (by feeling the Heat, and finding its distance from 12) must needs be able to tell you the true time of the Day.

OPERATION XXX.

To make a Dial to show the Hour when the Sun shines not.

The Construc-
tion.

PREPARE a Blaw Glas Bowl, (as in Scheme 36th) and describe on it (with their Respective Figures) all the Hour-Circles of the Globe, or as many as you think fit; then fixing it where you intend, and composing it truly by your Globe, if you place your self so at some Distance, that (a little Hole being made at each Pole, to wit at P p) you may see quite throu' the Bowl, 'twill follow that the Hour-Circle (suppose A, which the *Sun's* Picture appears on) will be the true time of the Day. I call this to know what a Clock it is when the *Sun* shines not, because now the least faint Appearance of him serves the turn, tho' it be not enough to cast any shadow; nay let the *Sun* be quite cover'd, and

and if you can but guess (by the *Adjacent Brightness*;) where about he is, you will be able to guess the *Hour* without any sensible Error; for the said *Brightness* appearing on the *Bowl* will be proportionably distant from the *Sun's* true place there, as 'tis from the *Sun* in the Heavens.

'Tis clear that the *Suns Picture* must fall (if any where) on the true *Hour-Circle*, because (by *Composing* the *Bowl* according to the true Position of the Heavens) the *Hour-Circles* of the one concur with the other, and fall exactly in the same *Plane*; therefore were your Eye in the *Center* of the *Bowl*, its true *Hour Circle*, (i.e. that which corresponds with the time of the Day,) would be just interpos'd between your Eye and the *Sun*; but since the whole *Axis* is the common Section of the *Hour-Circles*, let your Eye be but in any part of it, the same Interposition must happen; so that seeing the *Suns Ray* (by reason of the *Blue Colour*) penetrates not the *Glass*, his *Picture* must needs be on the outside of it, where the said *Ray* would have other ways past; Now the *Ray* that goes from your Eye throu' the two *Holes* being the *Axis*, therefore whilst your Eye remains in this Posture, it will follow that wheresoever you see the *Suns Picture* on the *Glass*, there his place must be, and consequently his said *Picture* must show the *Hour*.

OPERATION XXXI.

How to make an Horizontal Concave Dial by the Globe, and Geometrically also.

Compose so your Globe in the Concavity given (suppose *BAC* in Scheme 37.) that *A* the Center of the said concavity shall concur with the Center of the said Globe; then drawing your String over each necessary hour Circle on the Globe to the sides of the Concavity, mark as many Points, as shall be convenient for the Describing the corresponding hour Circles, and the Pin (*AD*) erected in the Nadir at *D* as high as the said Center *A*, I mean a Pin equal to the Semi-diameter of the Concavity, will with its Top always show you the hour.

The Construction.

Tho the former way be impracticable when the Hole is less

than The Geometrical way.

Q

The Demon-
stration.

than the *Globe*, yet it serves to illustrate and make easy the *Geometrical Operation*; for you have nothing (you see) to do, but to draw *hour Circles* within as you would without, were the said *Concavity* a whole *Sphere*, and then the *Top* of its *Semi-Diameter* (i.e. the poynt which lyes in the Center *A*) will perform the *Stiles* part; for since the *Sun* is every Hour (as we have before shewd you) in the same *Plane* of the true *hour Circle*, and since *A* the *Top* of the *Semi-Diameter* (being in the Center of the *Concavity*) is part of the *Axis* (or *Common Section* of all the *Hour-Circles*) it follows, that its *Shadow* must fall on the true *Hour*.

OPERATION XXXII.

How to describe Geometrically a Ceiling Dial.

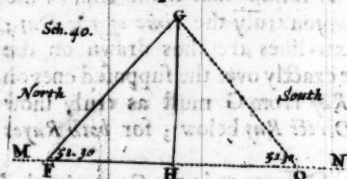
Being the *Glass* (which reflects the *Sun's* *Rays* to show us the *Hour*) is commonly fixt in the corners and by-places of *Windows*, the *Globe* can seldom be so well order'd (by reason of its Bulk) as to help us in the *Construction* of this *Dial*; therefore I shall only give you the *Geometrical* way, which is (as I take it) both short and new, and because these *Dials* have commonly the *Windows* (or inlets for the *Sun*) *Southerly*, for otherwise they will show but very few hours, we'll suppose ours also in the following Example to stand thus, and afterwards you shall see the difference between such a *Dial*, and those whose *Windows* have another *Aspect*.

The Construc-
tion.

First make on any *Part* of your *Trencher*, &c. an *Horizontal Dial*, as in *Scheme 38*. and fix in *O* its Center a *Thred* of a good Length, to wit *OP*; then fasten the said *Dial* so with a *Nail* to a Long *Masons Rule*, that its *Equinoctial edge* (*KL*) may lye upon the *Meridian* or *12 o'clock Line*; and having centered and plac'd Level a piece of *Looking Glass* (of the bigness of a *Three pence*) in the *Window*, or what convenient place else you please of your Chamber, (which we'll suppose to be *G*) find by the *Plumb* *AE* the Poynt *A* in the *Ceiling* (*WXYZ*) being the poynt (in *Scheme 39*.) directly over the said *G*, and draw throu' it a *Meridian line*, viz. the Line *AL*.

In the next place, fix one end of a piece of *Packthread* on *G* the

the Center of the *Glass*, and the other on some point of your *Meridian line* in such manner that it make an *Angle* with it of 51.30 . i. e. the *Angle of the Elevation*, which may be easily perform'd by the application of the side of a *Quadrant* to the said extended *Packthread*, and when 'tis right, let the Point thus found in your *Meridian line* be called B. Lastly, take the distance between the aforesaid Points A and B, and marking it, suppose at C, on the edge of your *Ruler* from O, the Center, (or fastning of the *Horizontal*) place so the said Rulers *Fiducial edge* (KCL) along the *Meridian line* on the *Cieling*, that the point C may lye juſt on A, and all is done; for then if you draw but the *Thread OP* ſtreight over each *Hour-line* of the *Horizontal*, it ſhows you where you are to draw all the fair *Lines* of the required *Dial*.



As for the truth of this *The Demonstration*, it appears (in *Scheme* 40.) by the right *Angle*

Triangles OGH and GHF, where HF is part of HM, a suppos'd *Meridian line* on the *Floor*, under that in the *Cieling*, G the *Station* of the *Glass* in the *Window*, H the Point under the said *Station*, as formerly A was the Point over it, and to facilitate the *Demonstration*, let us imagine GH equal to GA, i. e. that the *Glass* lyes in the middle, between the *Floor* and *Cieling*; This being ſo, ſuppoſe that GH (inſtead of repreſenting a Perpendicular Line in the *Wall* (as here we conceive it) had been a Perpendicular Stick, and that you were to deſcribe an *Horizontal Dial* on the *Floor*, whoſe *Stile* was to be the ſaid Stick, I ſay ſuppoſing this, you muſt (you know) to perform the *Operation*, produce the *Meridian Line* MH to ſuppoſe N, and faſtning a *Spring* on G, find in it the Point (v. g.) O for the *Center* of the *Dial*, (I mean a Point, to which a *String* being extended from G, makes with the *Meridian* (OH) the *Angle of the Elevation*) and ſo draw the ſeveral *Hour-lines* from the ſaid O according to their reſpective *Angles* and *Diſtances*; all which is expreſt at large in the third ** Scheme* or firſt *Horizontal Dial*; for there (you ſee) GH is a ** pag. 73.* Perpendicular *Stile*, ſhowing the *Hour* with its top, and that O

is the *Center* of the *Dial*, having a *Line* drawn to it from *G* making the *Angle* of the *Elevation* with the *Meridian* *OH*: Now since *O* in our present case is a point without the *Chamber* and consequently the *Line* *MH* cannot be produc'd to it, you must draw your *Thread* from *G* to the said *Meridian Line* (*HM*) within the *Chamber*, and find in it the Point *F*, to wit the Point where the said *Thread* *GF* makes with it an *Angle* equal to that of the *Elevation*, for thereby you will have the distance of *O*, your true *Center* from *H*, as being the distance of *F* from *H*, seeing the side *GH* is common, and the *Angles* in both *Triangles* equal: This being so, if you put out of the *Chamber* an *Horizontal Dial* whose *Center* shall lye on *O*, and its *Meridian Line* concurr with *H F*, 'tis but producing all its *Hour-Lines* on the *Floor*, and it must necessarily follow that *G*, the *Top* of the *Perpendicular Scile*, will show you truly the *time* of the *Day*; But by *Construction* all the *hour-lines* are thus drawn on the *Ceiling*, and consequently are exactly over the supposed ones on the *Floor*, Ergo, the *Reflex* *Ray* from *G* must as truly show you the *Hour* above, as the *Direct Ray* below; for both *Rays* are ever in the same *Plane*.

How this *Dial* is to be made when the windows be not *Southward*.

Nor is there to be any real *Difference* in the *Operation* tho' the *Chamber-window* should look another way; for you are only to remember, that whilst it enjoys the least Point of *South*, the *Center* of your *Dial* is without the *Chamber*; when it looks full *East* or *West* 'tis in the side or edges of it, and when it verges *Northward*, 'tis altogether within, so that in a full *Southern Aspect*, the said *Center* will be most abroad, and in a full *Northern* one the *Contrary*; all which plainly appears to any one, that will consider an *Horizontal Dial* truly plac'd (having a *Perpendicular* for its *Scile*) if he draws over the *Hour-lines*, a *Line* that shall represent the *aforsaid side* of your *Chamber* according to its *Position* and *Site*.

OPERATION XXXIII.

To make a compound Dial, to wit, one containing several
useful Operations.

Innumerable are the ingenious Dials that may be invented, but since we have been long enough on this Subject, either for my Reader's Speculation or Curiosity, I will now conclude, and that with a Recapitulation or summing up of much of what we have already said, by showing the Fabrick of a Compound Dial; that is to say, one that contains many useful Operations, besides the Hour; for nothing rubs up the Memory more efficaciously, or makes us more Masters of our Rules, than a Practical Example.

The said Dial shows as follows:

1. The Hour with us at all times.
2. The Hour in what other Countries you please.
3. The Sun's Place in each Sign.
4. The Day of the Month.
5. The time of the Sun's Rising and Setting.
6. The Sun's Amplitude.
7. The Sun's Height.
8. The Sun's Azimuth.
9. The Sun's Bearing according to the Points of the Compass.
10. The Proportion between Perpendiculars and their Shadows, and consequently the height of any Tower or the like.

To make then this Dial, you must first describe an Horizontal (as in Sch. 41.) about a Foot in Diameter, and let B the Center of the Plane be the Point, where an Erect, or Upright Stile (according to our Directions in the *first Horizontal,) shews you with its Top the Hour. Now because the Shade of an Upright Stile, unless it be very short, will presently fall out of the Plane, as well in the Morning as toward Night, there-
The Construction of it, as to the Hour at home. * pag. 73.

therefore it will be convenient to have your *Cock* or *Stile* made so, that *AB* the *Perpendicular* or fore-part of it (as in *Scheme 42.*) should stand at *B* the said *Center* of the *Plane*, to represent this *upright Stile*, and its *Angle AOB* at *O* the *Center* of the *Dial*, or *Point* from whence all the *Hour-lines* are drawn; for thus the side *QA* (making with the *Meridian line* at *O*, the *Angle* of the *Elevation*) represents the *Axis* of the *World*, and consequently casts its shadow on the *Hour-lines*, as the usual *Cocks* of all *Horizontal Dials* do.

The Construc-
tion of it as
to the Hour
in other pla-
ces.

2. Having chosen all the *Places*, which you desire from time to time to know what a *Clock* it is at, consider well your *Globe*, and find under what *Hour-Circles* the said *Places* lye; as for *Example*, suppose *Rome* lies under the 11 a *Clock Hour-Circle*, *Constantinople* under that of 10, *Aleppo* 9, &c. Place therefore the said *Towns* towards the *Limb* of your *Dial*, under the corresponding *Hour-lines*, and you will constantly know the time of the *Day* in the said *Places*, for calling it always *Noon* at each *Place* you seek after, you have nothing to do but to count the *Hours* from thence to the shade of the *Stile*; as v.g. If it be 4 a *Clock* with you in the afternoon, and you would know the *Hour* at *Aleppo*, let *Aleppo* be 12, and counting from thence (1. 2. 3. &c.) 'till you come to the *Hour* of the *Day*, (I mean the *Hour* then shown you by the *Shade*,) you will find it to be 7 a *Clock* there; for *Aleppo* is (you see) three hours *Eastward* of you; now had the *Hour* with you been 4 in the morning, you must have counted backwards, as 11, 10, 9, 8, and consequently you would have found it there 8 in the morning. In this manner then you must operate all along.

To find the
Sun's place
and day of
the Month.

3ly. and 4ly, Find by your *Globe* exactly the *Sun's height* every hour at his *Entrance* into each *Sign*, then take by the help of your *Sector* (*AB*, the *Erect Stile* in *Scheme 42.* being *Radius*) the *Tangent Complements* of the *Heights*, and putting one *Foot* of your *Compasses* on your *Dial* at *B*, make *Pricks* or *Marks* in each corresponding *Hour-line* accordingly; that is to say, if the *Sun* be high (suppose) 50 *Degrees* at 12 of the *Clock*, when he enters 8 or *♌*, then take the *Tangent* of 40 and prick that distance in the *Meridian line*, viz. from *B* to *f*; and if his height at 1 and 11 a *Clock* be (v.g.) 48 *Degrees*, take the *Tangent* of 42, and prick that distance in the 11 and 1 a *Clock line*, viz. from *B* to *b* and *g*, and when you have gone thus o-

over all the Hour-lines, no sooner will the *Sun* come into δ or π but the *Shade* of the *Point* or *Apex* of the *Stile* A B will fall every hour on the aforesaid *Pricks*, and consequently show you the *Suns* place in the *Ecliptic*. In like manner you must do with the rest of the *Signs*, and then with the 10th *Degree* of every *Sign*, placing itill the *Character* of each *Sign* about the *Limb* of your *Dial*, near the last *mark* or *Prick* belonging to it. This being done, see by your *Globe* what day of the month corresponds with each *Sign*, and what with their *Subdivisions*, and if you mark this (as the said 4th *Scheme* shows you) on both sides of the *Meridian*, then the said *Pricks* will (by the help of the *Shade* of the top of A B) show you also the day of the month. I mention here *Pricks* not only as an easier way, but a better way than *Lines*; for besides the great difficulty of drawing them, they embarras and confound a *Dial* very much, especially if there be many of them; whereas the said *Pricks* are never out of an *Hour-line*, and consequently take up no new room. Now to avoid Confusion and Mistakes, I would have the said *Pricks* of 3 sorts at least, for if one Row were (*v.g.*) *Astericks* and another *Crosses*, and a 3d *Plain Pricks*, you would then know at first sight, to what *Sign* or Day of the month any of them belongs.

5ly. Instead of troubling you with deviding the Circle To find the
G K L T (the upper part of the Border of the *Dial*) for the
finding out the time of the *Suns* Rising and Setting, you need
only consult the Days of the Month on your *Globe*, first, when
He rises earliest, Secondly, when He rises at 4 a Clock, Third-
ly, when at 4 $\frac{1}{2}$; Fifthly, when at 5; and in the like Proportion
go on, till the Days come to their greatest Decrease, and put-
ting the said days of the Month in Order (as they are in the
Scheme) under the corresponding Hours on the morning side
of your *Dial* for his Rising, do the like for his Setting on the
Evening side of it, and you may perform the Operation with
sufficient Exactness. In like manner you are to proceed for the
Quarters, *half Quarters*, &c. if you would have them exprest.

6ly. To avoid also the trouble of deviding the Circle To find the
 $\lambda \mu = \sigma$ according to the *Suns* Diurnal Increment and Decre-
ment in Amplitude, you need only find by your *Globe*, what the
said Amplitude amounts to on every of the aforementioned
Days (which are markt on your *Dial* for the *Suns* Rising and
Setting, *Suns* Ampli-
tude.

Setting) and then put it in Figures under each Day, as the Scheme shews you.

To find the Height of the Sun.

7ly. Open your *Compasses* at the *Tangent* of 28 Degrees (A B being the *Radius*) and putting one Foot on B describe the Circle X Y Z, afterwards describe another according to the *Tangent* of 35 Degrees, then a third, according to that of 40, and so on in the same Proportion as far as your *Plane* permits. Now if you mark these *Circles* with the Figures of the *Complement* of their Degrees, that is to say the Circle of 28 Degrees with the Figure 62, that of 35 with 55, that of 40 with 50, &c. you will always know the height of the Sun, for what Circle so ever the Shade of A B touches with its Top, that will be the requir'd Height; and if it falls between 2 Circles, 'tis but considering which of them it comes nearest to, and then you may guess at the Height with sufficient exactness.

To find the Suns Azimuth and Bearing.

8ly, and 9ly. Devide one of these *Circles* viz. S E A W N into Degrees, and under each 11 Degree and $\frac{1}{2}$, place the several Points of the *Pixidis Nautica*, or *Mariners Compass* in the Order as they are express'd in our said Scheme, and you will not only have (by the Shade of A B) the Suns *Azimuth* at all times, but see also how he bears from you according to the Points of the *Compass*; and if the Shade be at any time too short, lay on it but a *Ruler*, *Label of Paper* or the like, and that will truly lengthen the said Shade, and resolve your Question.

To find the Proportion of Perpendiculars to their Shades.

10bly. Devide A F the Northern half of the *Meridian*, as many times as you can by the *Stile* or *Radius* A B, and then each *Devision* into ten equal parts (as you see it done in the said Scheme) and by it you will know at all times the Proportion between any *Perpendicular* and its Shade, and consequently, (besides many other things) the height of any Tower, Tree or the like, for having found the Sun to be (suppose) 25 Degrees high, and that the Circle of *Altitude* cuts the Line A F in the 22 *Devision*, if therefore you measure the Shade of your Tower, and finding it (for Examples sake) to be 66 Yards long, you have what you seek; for as the said 22 is to 10 (the *Stiles* height) so is 66 the length of the Shade to 30 the height of the Tower.

So much then for the Construction of *Dials*. And now let me desire all those that are pleased to follow this Geometrical way, (which perchance is as expedite a one, and as free from blind Lines

Lines as can be,) not to rest satisfy'd till they fully comprehend what they do; for the *Mechanical way* of *Dialling* is as soon lost as learnt, it being impossible (without continual Practice) not to forget the *Rules*, especially if one can make many *Dials*; when as a man that understands the reason of the *Operations* (by having in his Head a true Idea of the *Sphere* and its *Projection*) will 20 years after without *Memorandums* or *Notes*, be able (reflecting but a little) to make not only all *Dials* he formerly knew, but new ones also at first sight.

To Conclude, I here present my *Reader* with the *Globe* in a new Dress, for being painted or stain'd on *Marble* (according to *Sch. 43.*) 'twill be fit for any *Garden* or open *Portico*; and least it might appear too plain, the corners of its *Base* or *Pedestal* may be adorned with handfom well turn'd *Branches*, which not only embellish the whole *Machin* by their Make, But hold our *Bowls* of *Glass* and *Wax* for use, also.

For on the *First Corner*, to wit, That markt with *A*, there is placed (as a *Rarity*.) *The blind man's * Dial*. On the *Second* markt with *B*, *That Dial* that shows the *Hour*, when the *Sun* shines, which will be often very useful. On the *third*, markt with *C*, there is an *Armillary Wyer Sphere* having a *Vane* on the *Top*, that continually shows on the *braß Plane* within (graduated and Nautically Character'd) from what *Quarter* the *Wind* exactly blows; as also, (if you turn the said *Vane* into the *Plane* of the *Sun*) his *Azimuth* and *Bearing*. Besides, the *Sphere* (being an *Horizontal Concave Dial*) shows the *Hour* too; for the *Shade* of the *Pin's* top in the *Center* ever fall's on the true *Hour-Circle*, as I show'd in the ** Construction* of such a *Dial*. And by the way you must know this *Branch* stands not in it's true place in the *Scheme*, I mean on the *third Corner* of the *Base*, because in *Perspective* 'twill fall on the *Globe* it self, and consequently not appear well to the *Eye* in a *Picture*. Lastly, on the *fourth Corner* markt with *D* there is another *Glass Bowl* of the former *Dimension*, containing orderly all the *Constellations*, and remarkable *Stars*, and therefore, if you know the *Hour*, it will compose the said *Bowl* or *Globe*, and so represent the then position of the *Heavens*; but (tho you are *Ignorant* of the *Hour*) if you see a known *Star*, and move the *Bowl* on its *Axis*, till the painted *Star* on it lyes just between your *Eye* and the *Real* one, you have the *Hour*, and consequently may know (the *Globe* being

The description of the Branches or Embellishments in Scheme 43.

* p. III.

† p. II2.

* vid. p. II3.

now Compos'd) any Star or Constellation above the Horizon; for the Axis of this Bowl having one end pointing directly to the North Pole, and the other fixt in the Center of a Rundle containing on its Limb the Days of each Month, fitted to the right Ascension of the Stars, and moving also on a Plane divided into 24 equal parts, figured with the hours of a Natural Day, 'twill follow that the Day of the Month (when the Globe is Compos'd) must lye on the true Hour, as the true Hour mov'd to the Day of the Month must Compose the Globe, as is before hinted. These short directions are sufficient for any Mathematician, or Instrument-Maker; and as for the Branch it self, 'tis (as you see) not in its true Place for the above mentioned Reason.

F. Moxon To the Reader.

*P. 71.

HAVING Courteous Reader* engaged to show you the Problems and Operations on the Sector, which the Noble Author supposes every one (that studies the Geometrical way of Dialling) to know, I shall here begin.

I. Upon a Line given (A B) to erect (C D) a Perpendicular.

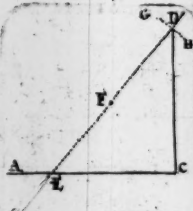


IF there be a Point (as C) given in (A B) the Line on which the Perpendicular is to fall, Mark on both sides of the said Point (with your Compass) the equidistant Points M and N, then opening them at pleasure, put one foot on M and describe the blind Arch E E, and putting the other Foot in N, describe the blind Arch G H, and the fair line from (D) their Intersection to the Point C, will be the Perpendicular requir'd. Now if you have no Point assign'd (in the said Line (A B) to terminate your Perpendicular by, take two Points there at pleasure, as suppose M and N, and opening how you will your Compasses, describe the blind Arches E F and G H above your Line, and O P and Q R below it, and the Intersections

tersections of these *Arches* (to wit, D and S) will be two points to draw your *Perpendicular* by.

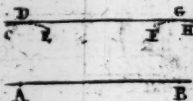
II. Upon (C) the end of (A C) a given Line, to draw (D C) a *Perpendicular*.

OPEN your Compasses at a convenient width, and putting one Foot on C, let the other (within reach of A C) mark any where, as at F: then touching or cutting from thence the said A C (with the moving Foot of your Compasses) at, suppose, E, and describing on the other side of F the blind Arch G H, lay your Ruler on F E, and it will cut the said Arch, at, suppose D, so that D C will be the requir'd *Perpendicular*.



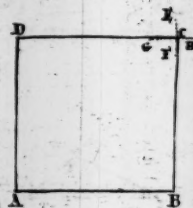
III. A Line (A B) being given how to draw (D G) a *Parallel* to it.

HAVING taken two points in the said Line, as suppose A and B, open your Compasses at what width you please, and putting one foot on A, describe the blind Arch C D E, and putting one foot on B describe the blind Arch F G H, then if you lay your Ruler on the highest part or greatest Extuberancy of the said Arches, to wit on the Points D and G, the Line so drawn will be the requir'd *Parallel*.



IV. To describe a true Square.

A B being a Line, as long as the side of the Square you design, erect on the end A, the *Perpendicular* D A of the former length; then taking between your Compasses the said A B, put one foot on D, and describe the blind arch E F, and again putting one foot on B, describe the blind arch G H, to cut E F, and if from their Intersection C, you draw the fair lines C B and C D, you have a true Square.



V. To draw an Oblong, or (as they commonly call it)
a Long Square.



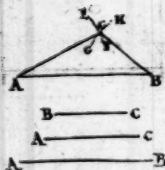
AB being the longest side of this *Square*, erect on the end *A*, the Perpendicular *DA*, of the length of the shortest; then taking between your *Compasses*, the line *AB*, put one foot on *D*, and describe the blind arch *EF*: and taking between your *Compasses* the line *AD*, describe the blind arch *GH*, to cut the said *E F*, and if from their Intersection *C*, you draw the fair lines *CB* and *CD*, you have the *Square* you design.

VI. To Describe an equilateral Triangle, or an *Iso-*
celes.



OPEN your *Compasses* at *AB*, being the side of the *Triangle* you design, and putting one foot on *A*, describe the blind Arch *EF*, and again putting one foot on *B*, describe the blind Arch *GH* to cut the said *EF*, and if from their Intersection *C*, you draw the fair lines *CA*, and *CB*, you have a true *equilateral Triangle*; Nor is there any difference in the Description of the *Isoceles ASB*, for the only difference between them is, that the sides *AS* and *BS* of the *Isoceles* are longer (or if you please they may be shorter) than the Base *AB*, whereas all three sides are equal in the *equilateral Triangle*.

VII. To make a Triangle of three given Lines.



SUPPOSE the first line given be *AB*, the second *AC*, the third *BC*, and that you are to make a *Triangle* of them: let *AB* be the Base, and taking the given line *AC* between your *Compasses*, put one foot on the Base at *A*, and describe the Blind Arch *EF*, then taking the given line *BC*, between your *compasses*, put one foot on the Base at *B*, and describe the Blind Arch *GH*, to cut the said Arch *EF*, and if you draw lines, from their Intersection at *C*, to *A* and *B*, on the aforesaid Base, you have your intent.

VIII. To

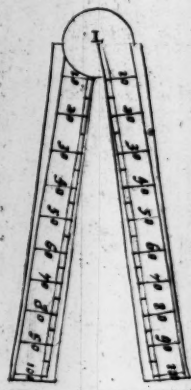
VIII. To describe an Oval.

CROSS R Patright Angles with I M, and taking with your Compasses (on the said lines from the intersection O) equal distances, to wit, O A, O B, O C, and O D, and draw through the point C, the lines A K and B H, each equal to twice A C, as also throu' D the lines A N and B L, each equal to twice B C, then A and B being Centers, describe the *Arches* K P M, and H L R, in like manner C and D being Centers, describe the *Arches* H I K, and L M N, and the figure thus drawn will be a perfect Oval.



So much for the Geometrical Problems necessary for Dial-ling, and as for the Instrumental ones, i. e. those performed by the Sector, they are, as I may say, of two sorts, some belonging to one side of it, and some to the other; for the side marked with L is divided into 100 equal parts, and called the LINE of LINES, and the side marked with S, the LINE of SINES. First then of the LINE of LINES, which by the way, tho' it be divided (as I said) but into 100 parts, may yet stand for 1000, if you fancy every 10 Divisions a Line of 100 parts, and in like manner it will stand for 10000 parts, if every division be deemed 100, therefore a Line (v.g.) of 75 equal parts, may be express'd by 75 of those Divisions, or by $7\frac{1}{2}$ or by $\frac{1}{2}$.

Of the Sector.



The Use of the LINE of LINES marked with L.

I. To divide a Line into any number of equal parts.

SUPPOSE your Line were to be divided in 23 equal parts, take it between your Compasses, and opening your Sector, place one foot of your said Compasses on the 23 division of the Sector, and the other foot on the 23 over against it, and the distance between the Figures 1 and 1, on the said Sector will give you one equal Division of your Line, and the distance between 2 and 2, will give you two equal Divisions of it, and in this manner proceed till you quite run over it, as you design.

II. To.

II. To find the proportion between any two Lines.

SET over the greater *Line* at 100, and 100 on the *Sector*, then taking the lesser between your *Compasses*, find where it will be just set over also, or lye *parallel* to the former, which hapning suppose at 50 and 50, you may conclude, that the *Proportion* required, is as 100 to 50.

III. To divide a *Line* as any other *Line* proposed is divided; that is to say, according to any *Proportion*.

SUPPOSE you saw a *Line*, containing 65 equal parts of the *Sector* divided into three pieces, the first containing five equal parts of the *Sector*, the other fifteen, so that the last must be 45; then suppose you would divide (after this *proportion*) another *Line*, containing but thirteen equal parts of the *Sector*; Open your *Compasses* at 15, or length of the *Line* to be divided; and putting it over at 65, and 65 on the *Sector*, the *Parallel* at 5 and 5 will be the first division of the *Line* to be divided, and one equal part of the *Sector* in value; the *Parallel* at 15 and 15 will be the second, and three equal parts in value; and the remainder (being 9 in value,) will be the third; and thus you may do in all other cases.

IV. To increase or diminish a *Line* in any *Proportion*.

SUPPOSE the *Proportion* were as 4 to 7, take the *Line* given between your *Compasses*, and setting it over on your *Sector*, at the Figures 4 and 4, the distance from 7 to 7 will be a *Line* increase (in respect of the given one) as is the *Proportion* of 4 to 7. In like manner you must do, if any other *Proportion* were requir'd.

Now if you would diminish a *Line* as is 7 to 4, put over the *Line* given at 7 and 7, and the distance of 4 and 4 is the requir'd *proportion*.

V. Two Lines being given, to find a Third Proportional.

FIND by your *Compasses* how many parts of the equal Divisions of your *Sector* will measure both your given *Lines*; so that supposing the one to contain 10 parts, and the other 20, set the second *Line* (i.e. the *Line* 20) over at 10; and 10 on the *Sector*, and the distance or *Parallel* at 20, and 20 on the *Sector* will be 40, the requir'd *Proportional*.

VI. Three Lines being given, to find a Fourth Proportional.

THE value of the *Lines* being found as before, and supposing the first to be 10, the second 20, the third 30, put over the second *Line* (to wit, 20) at 10 and 10. (the value of the first *Line*) and the distance or *Parallel* at 30 and 30. (or value of the third *Line*) will be 60, the required *Proportional*.

Of the Use of the LINE of SINES, marked with S.

I. How to find the Sine of any Angle, according to any Radius.

SUPPOSE the *Sine* of the Angle you require be 50, take the *Radius* between your *Compasses*, and put it over at the extremity of the *Sector*, that is to say, at 90 and 90, and the *Parallel* at 50 and 50 will be the *Sine* of 50 Degrees, according to that *Radius*.

II. How to find the Chord of any Arch.

SUPPOSE you would have the *Chord* of an *Arch* of 50 Degrees, open your *Compasses* at the length of the given *Radius*, and put it over at 90 and 90, then take with your said *Compasses* the *Parallel*, at the *Figures* 25 and 25 on the *Sector*, (i.e.



at

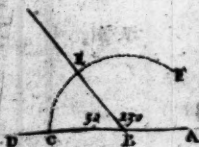
at the *Figures* of half the *Degrees* given) and prick or measure it twice upon any streight *Line*, and that will be the *required Chord*.

III. How to make an Angle of any value, as also how to find the value of any Angle already drawn.

Suppose you are to make an *Angle* of 50 *Degrees*, draw a *Line*, as (for Example sake) A D, and taking any Point in it, as B, open your *Compasses* to a convenient *Radius*, and put one Foot on B, and describe the blind *Arch* C F, then taking between your *Compasses* the *Chord* of 50, according to the *Radius* of the said *Arch*, put one Foot on C, and the other marking at Suppose E, draw the *Line* B E, and you have the *required Angle*, to wit, the *Angle* E B C. But if the *Angle* you would make be above 90 *Degrees*, as suppose 130, make the *Angle* of its *Supplement*, viz. the *Angle* of 50 as before, and the *Angle* on the other side, viz. E B A will be the *Angle* you look for.

Here therefore you see how to find the value of any *Angle* already drawn, as suppose the *Angle* E B C, since 'tis but describing a blind *Arch*, as C F, and setting over (on the *Sector*) the *Radius* of the said *Arch* at 90 and 90, for if you observe where the measure of this *Arch* (viz. C E) marks a *Parallel* on the *Sector*, as before, the *Figures* there (to wit, 25) being doubled (and amounting consequently to 50) will be the requir'd *Angle*.

As for the *Tangent* and *Secant* of any number of *Degrees*, the *Noble Author* has himself shew'd you how to find them at pag. 71. and so gentle Reader having finish'd my promise, I bid you Farewel.



SECT. VI.

Of the STARS.

AS for the Stars, it is not my set business to meddle with them, nor is there any Instrument that so naturally resolves all the usual Questions concerning them, as the *Cælestial Globe*; for there things appear as they do in the Heavens themselves, But because such a *Globe* is not always at hand, I will shew you how its most necessary Operations may (in case of necessity) be perform'd, even by our present *Globe*, and then I shall treat of the *Pedestal*, on which all the appearing Stars are truly projected.

The usual and most necessary Operations of the Cælestial Globe in relation to the Stars are these.

1. To find the Declination of any Star.
2. To find the Right Ascension of any Star.
3. To find the difference between the Suns Right Ascension, and that of any Star, or the difference between the Right Ascensions of any two Stars.
4. To find the true place of any Star on the *Globe*, i.e. the Point that corresponds there, with its then Place in the Heavens.
5. To find the Bearing of any Star according to the Points of the *Compass*.
6. To take the height of any Star you see.
7. To find the height of any Star by the Hour tho' unseen.
8. To find the Azimuth of any Star.
9. To find how many Hours any Star stays above or below the *Horizon*.
10. To find when any Star rises or sets.
11. To find what a Clock 'tis by any Star.
12. To know the name of any Star you see.

OPERATION I.

To find the Declination of any Star.

AS for the Declension of the Stars, since the Cælestial Globe and other Instruments, that shew their motions, perform this Operation by their make (for on them the Stars are always plac'd, according to their respective Declensions) we shall require here a proportionable Concession, viz. That in some of the vacant parts of our Globe there may be a little Table, containing the Declension and Magnitude of the most noted Stars, as also the Degree of the Ecliptick, which agrees with their respective Right Ascensions: that is to say, a Table containing their Declension and Magnitude, with the Sun's Place in the Ecliptic, when his and their Right Ascension are the same; and the said Table may be made in the following manner.

The Table for the Stars.

| Mag. | Name. | Declension. | Deg. Eclip. |
|------|-------------------|-------------|-------------|
| 1. | Bulls Eye. | 15 48. | II 6. |
| 1. | Lions Heart. | 17 33. | ♏ 26. |
| 1. | Arcturus. | 51 4. | ♈ 1. |
| 2. | Little Dog. | 6 3. | ♐ 19. |
| 2. | Medusa, or Algel. | 39 40. | ♏ 13. |

And so for as many as the Globe-maker thinks fit to express.

OPERATION II.

To find the Right Ascension of any Star, v. g. of the Lion's Heart.

HAVING found by the Table, that the Lion's Heart has the same Right Ascension with the Sun, when he is in the 26 of ♏, draw your String over that Degree of the Ecliptic, and it will cut the Equator at almost 148 Degrees, for the Stars Right Ascension.

OPE.

OPERATION III.

To find the difference between the Suns Right Ascension, and that of any Star, as also the Difference of the Right Ascensions of any two Stars.

HAVING found by the former Operation, that the Right Ascension of the Lion's Heart is towards 148 Degrees, and that the * Suns (on viz. the 10 of April) is near 28, the difference * Op. 17. Sect. 1. (by Subtraction) will appear to be about 120 Degrees, or (by the intermediate Hour Circles) 8 hours. In like manner having found (for example sake) the Little Dogs Right Ascension, to be about 110 Degrees, the difference between it and that of the Lions Heart is 38, or 2 hours and a half. pag. 19.

OPERATION IV.

To find the Place of any Star on the Globe, i. e. the Point that corresponds with its then Place in the Heavens.

HAVING found by the foregoing Operation, that the difference between the Suns Right Ascension and the Lions Heart, is about 120 Degrees, or 8 hours, subtract the said hours (for so much the Sun Rises and Sets now before the Star) from the time given (suppose from 10 at Night) and the remaining 2 hours shows you, that the Star is at that moment in some part of the Hour-circle of 2 in the afternoon, or thereabouts; so that the Bead rectify'd to the Stars Declension, and moved on its Noose from the Pole to the said Hour-Circle, determines the very Point or Place requir'd. The like may also be performed by your Compasses open'd from the Pole, at the Complement of the Stars Declension.

But here you must remember that the readiest way still to find the present place of a Star is by its Almucantar and Azimuth; for where these Circles intersect, there the Stars then Place will be; and as for the Almucantar and Azimuth of any Star, they are found by the 6th, and 8th, Operation of this Section.

A Memorandum.

OPERATION V.

To find the Bearing of a Star at all times.

HAVING found the true Place of the *Lions Heart* by the former Operation, if you draw your String over it from the *Zenith*, 'twill cut the *Horizon* at or about S. W. for its then Bearing.

OPERATION VI.

To take the Almucantar or height of any Star you see.

BECAUSE Stars cast no shade, you must take their Heights as you do the *Suns* when he is overcast, and therefore consult the first Operation of the first * Section, or the 5th. of the * 4th. Section.

* p. 6.
* p. 68.

OPERATION VII.

To find the height of a Star at any time, by the hour tho' unseen.

THE Hour being (v. g.) 10 at Night, on the 10 of April; the *Suns* place is where his Parallel cuts the 10 a Clock Hour Circle, so that knowing by the difference of their Right Ascensions that the *Lions Heart* is (v. g.) 8 hours behind the Sun, you may conclude the Star to be somewhere in the Hour-Circle of 2 in the afternoon, to wit, in that Point, which answers to the said Stars Declension; having therefore its Place, draw but your String from the *Zenith* over it, and mounting your Bead to it, if you move your said Bead to the Meridian or Quadrant of Altitude, 'twill lye on or about the 45th. Degree for the required Height.

OPERATION VIII.

To find the Azimuth of any Star.

FInd but the *Lions Heart's Bearing*, or his then true *Place* in the Heavens as before, and the *String* will cut the *Horizon* on its true *Azimuth*. Now if you see the *Star*, you may perform this *Operation* without any of the former *Postulats*; for placing your *Globe* on a *Meridian Line*, and holding your *String* streight from the *Zenith*, do but move it in that posture by the direction of your *Eye* (as we shew'd you in the first * *Section*) till it be in the same *Plane* with the *Star*, and the Degrees of the *Horizon* under your *String*, give you the required *Azimuth*, which will now be about 45 Degrees Westward. *Op. 5. may 22. p. 10.

OPERATION IX.

To know how many hours any Star stays above or under the Horizon.

Rectify the *Bead* to the *Declension* of the *Lions Heart*, and moving your *String* on the *Noose* from the *Pole*, till the said *Bead* touches the *Horizon* on the *West side*, see what *Hour-Circle* cuts with it there, and you will find it to be that of 7 and a quarter or thereabouts; and this doubled (making in all some 14 hours and a half) gives the true time of its stay above the *Horizon*; so 4 and three quarters doubled (I mean the *Hour-Circle* which Intersects with it on the *East side*) gives you 9 hours and a half for its stay below the *Horizon*.

OPERATION X.

To find when any Star Rises or Sets.

Having found by the third *Operation*, the difference between the *Suns Right Ascension* and that of the *Lyons Heart* to be 8 hours on the 10th of *April*; and having also found by the fore-

foregoing Operation, that it *Rises* where the Hour-Circle of 4 and 3 quarters cuts the *Horizon*, and *Sets* where that of 7 and a quarter do's the like, add the 8 hours difference (because the Star is now so much behind, or too slow for the Sun) to 4 and 3 quarters, which making 12 and 3 quarters in all, shows that the Star rises at 12 a Clock, and 3 quarters in the afternoon; and by adding it to the aforesaid 7 and a quarter, that it sets at 15 and a quarter, to wit, at 3 and a quarter in the morning.

OPERATION. XI.

To find what a Clock 'tis by any Star.

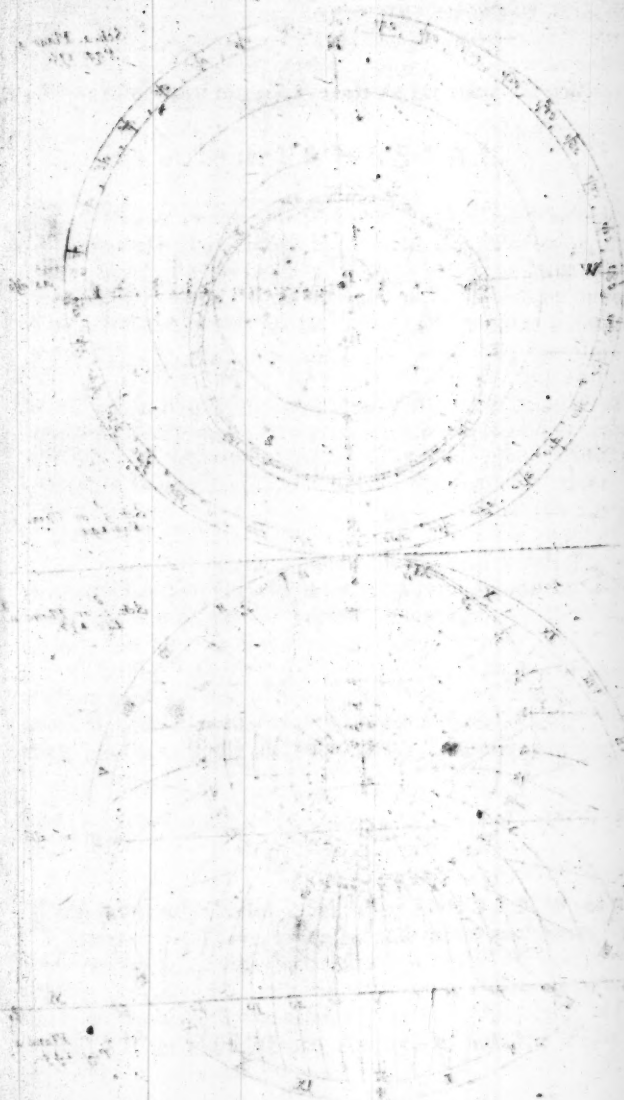
HAVING (*v.g.*) on the 10th. of *April* found the true place of the *Lyons Heart*, on the *Globe*, by some of the former ways, as (for Example) by its *Height* and *Azimuth*: I say, having thus found the *Stars true place* on your *Globe* (which happening (*v.g.*) to be in the 2 a Clock Circle) find by the third Operation the difference between its and the *Suns right Ascension*, which being 8 hours, add it to the said 2 (for the Star is as we said 8 hours now behind or too slow for the Sun) and the then true hour will be 10 at night.

OPERATION XII.

To know the Name of any remarkable Star which you see.

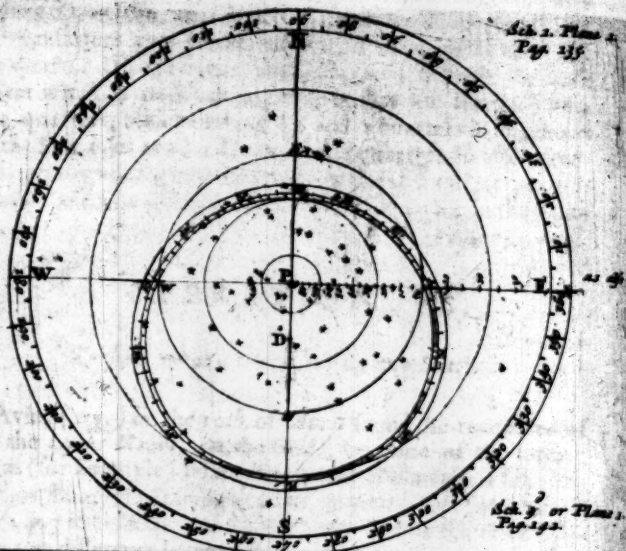
BY a *Stars Height* and *Azimuth* you may (as we have shew'd you) quickly find its present true place on the *Globe*, and consequently its *Declension*, as being the nearest distance between its said Place and the *Equator*; so that your Tables of Declension gives you its Name; and if there should be two of the same Declension then their right *Ascensions* (being different) will resolve the Doubt.

To conclude, all the former Operations may be yet more readily performed, and that without any Table, if the Globe-maker place 10 or 20 of the most noted Stars (which will be enough to
sa-

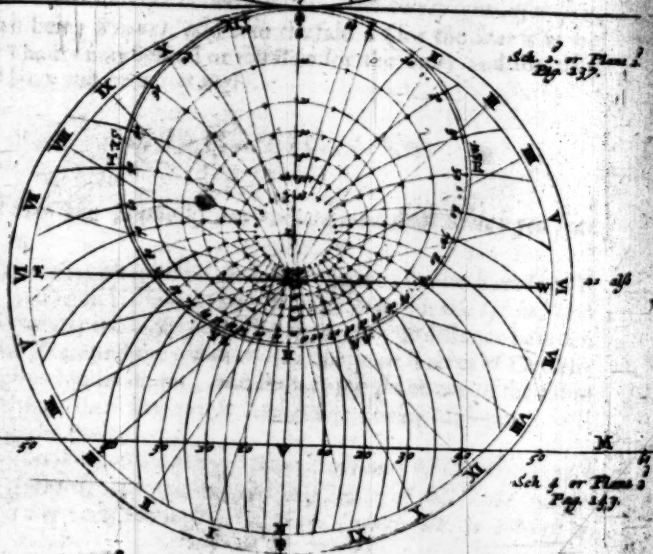


Handwritten text, likely a description or title, written vertically along the right side of the page. The text is faint and difficult to read, but appears to be a single column of writing.

These schemes are properly Sch. 3 Or 4 belonging to Page 135 as showing the way to regulate the Projection but they will serve for Sch. 1. & 2 Page 135. if one of higher & complicated are supposed to be drawn on a plane & one of lower a line some three feet of diameter to each hour in Sch. 3 Or 4. Moreover or somewhat enlarged line by Sch. 1.



Sch. 3. or Plane 1.
Page 135.



Sch. 4. or Plane 3.
Page 137.

satisfy any ordinary curiosity on the Globe it self, according to their true Longitude and Latitude; for then their Declensions, Parallels, and right Ascensions appear in a manner at first view, which must needs therefore facilitate the other Operations.

of the PEDESTAL.

THIS you see that our Globe (tho' it be a Terrestrial one) may (in case of necessity) be serviceable in relation to the very Stars; but because all Operations that have the least Reflection in them, seem intricate and troublesome to some, I have here adjoyned (for them that will be at the Expence of the best sort of these Globes) a most Facile way, that shall resolve in an instant, all the former Questions and more; for there is not only a Stereographical Projection on the Pedestal of the appearing Stars in our Horizon, but one also so ordered, that it obviates the inconveniences which make *Stofflers* admirable *Astrolabe* so much neglected of late; for some say, there is no finding a Star on it without much poring, tho' we should know near what Constellation it lyes; others, that when we see a Star there, we are still ignorant to what Constellation it belongs; many quarrel at the great confusion which the Azimuths, Almucantars, and other Circles express on it make; and some again object, that the numeral Figures belonging to the said Circles are oftentimes so hid by the solid part of the Rete, that we cannot without a new trouble and motion perform the intended Operation. I say, this Projection on the Pedestal (besides several other things) obviates these inconveniences, as you will presently see.

The Explanation of the Circles and Lines of the whole Projection on Pedestal.

THE uttermost Circle (in Sch. 1) or Limb **SENW** of the lower or first Plane, represents *Circulus maximus semper latens*, or (if you think that too large) what Parallel you please. It may be conveniently nine Inches or a little more in Diameter, if the Globes be a Foot, and being of fine Pastboard or the like substance, it is to be let into the Pedestal, which

Of the first Plane and its bigness.

which is purposely made *Cradle* or *Frame* wise, that it may (by your hand underneath) be easily turn'd round, and be also taken quite out, if any particular or extraordinary occasion should require it; Nay, the whole *Pedestal* may be pulled off, (if you think fit) from the handle or *Fulcrum*, and us'd apart as a distinct *Instrument*.

Of the Circles
and Stars on
it, and how
they are plac-
ed.

2. The great Circles described on it are only two, viz. the *Aequator* ($\gamma A \approx x$) and the *Ecliptic* ($\gamma S \approx w$) divided into the 12 *Signs*, with their gradual subdivisions. Now (since it will be no incumbrance to your *Plane*) you may express on it also (if you please) the two *Tropics*, by two fine Circles, that of *Cancer* touching the *Ecliptic* at S , and that of *Capricorn* at w . And as for the *Limb*, it is divided into 360 *Degrees*, for being in Projection greater than the *Aequator*, 'twill prove more useful in all the *Operations*, that concern such Divisions. Nor are the Circles or Stars placed here as on the *Globe* (I mean according to the *Degrees* of a *Quadrant* equally divided) but *Stereographically* projected by half *Tangents*, i.e. as they would appear and fall on an *Equinoctial Plane*, or a *Plane* parallel to it, were our Eye in the *Pole*, of which more hereafter, as also the *Centers* and *Radii*'s of each Circle, when we come to the *Description* and *Demonstration* of the whole *Projection*; and in this manner also (to wit, by half *Tangents*) the *Line P. E.* is divided, which shows the *Declension* of any *Star*.

Thirdly. The *Stars* being all plac'd on this *Plane* according to their respective *Right Ascensions* and *Declensions*; and by the way, when you once know how to find by this *Projection* the *Right Ascension* and *Declension* of a *Star* (as you will presently do by the following Instructions, that concern operation) you will then also know by the help of *Astronomical Tables* (which give each *Star's* *Right Ascension* and *Declension*) how to place them here: May, the *Stars* being all plac'd on this *Plane*, according to their respective *Right Ascensions* and *Declensions*, they are to be Marshall'd and reduc'd into *Constellations*; and therefore you must suppose either fit *Pictures* drawn about them to express what they are, or that the uttermost *Stars* of each be join'd by a fine *Prick's Line*, which will give you perchance, the most clear and just representation of them, and consequently prove the easiest

easiest way for the finding them out in the Heavens; But since *Pictures* have conveniencies and great ones also; for thus without consulting the written names, we cannot only find presently (even a far off) the *Constellation* we seek after, but know at the same time the *Place* of each *Star* in it, which *Place* for the most part gives the *Star* its ordinary Name: I say, since *Pictures* have great Conveniencies, let them be us'd; but then they must be as faintly and simply express'd as can be; for deep shadows, and unnecessary Flourishes both distract the Fancy, and cause even the *Stars* that are express'd to be less conspicuous and observ'd.

Fourthly, When the first *Plane* is thus garnished and plac'd *Of the second* in its *Frame*, there is another of the same bigness, either of *Plane*, and it's bigness. *Glass*, or *Talk* (represented by *Scheme* the second) to be put over it, and fixt or fastned in the uttermost *Molding* or *Ledge* of the *Pedestal*. And here be pleas'd (for distinction sake) to remember, that by the Terms *First*, and *Second*, these two *Planes* are distinguish'd, and that by *Projection* is meant the whole *Pedestal*, or *Astronomical Machin*, which (as I said) may be taken off, and us'd apart, as a particular *Instrument*.

Lastly, the second *Plane* (represented, as I said by *Scheme* the second) has its *Limb* S. E. N. W. divided (besides the subdivisions or *Quarters*) into 24 equal parts, by so many *straight Lines*, drawn from the *Center P*, and figur'd (I. II. III, &c.) according to the hours of a natural *Day*. As for the *Circle* H R S T, it represents the *Horizon*; and the *Circular Pricks* within it give the *Almucantars* and *Azimuths* of every 10 Degrees; for (on the one side) if you consider the said *Pricks* as so many *Circles* ascending from the *Horizon* towards the *Zenith*, the *Figures* along the *Lines*, P S and P N give you from the *Horizon* upwards the height of that *Star* which touches any of them. On the other side, if you consider them in *File*, (I mean as so many *Arches* passing thro' the *Zenith*, and terminating in the *Horizon*) their distance from P S (the *Southern part* of the *Meridian*) shows the *Azimuth* of the *Star* next any of them, by the *Figures* round the *Horizon*; and least you might not readily distinguish *Arch* from *Arch*, if the *Pricks* were all of the same kind or *Species*, there are two sorts here, viz. one of plain

and simple *Pricks* the other of small *Astricks* alternatively plac'd; so that 'tis but observing of what *Species* the *Prick* next a *Star* is, (as suppose an *Astrick*;) and then following with your Eye a *File* or *Arch* of *Astricks* 'till you come to the *Horizon*; for the *Figures* at their termination there give you the requir'd *Azimuth*. Thus then the confusion which the several *Almucantars* and *Azimuths* would make (were they all describ'd on the *Plane*) is avoided, seeing the *Plane* is now less fill'd than if the *Almucantars* were only exprest on it; for disjoyn'd *Pricks* circularly plac'd occupy not the room of a continued Circle, and yet each *Row* or Circle of the said *Pricks* perform both the forementioned Offices.

How to operate by the Projection or Pedestal.

FIRST the Reader must remember, that I call *Rising* the first *Plane*, the placing and adjusting it so that all the *Stars* may appear above and below the *Horizon*, as they then really do in the *Heavens* themselves; which *Operation* being a main and principal matter (for all the other are in Truth but so many *Deductions* or *Corollaries*) I will now begin with it; nor is there anything here requir'd but the height of some *Star* in view (as the *Lion's Heart*, or the like) which you may find by the *Globe* as you do the * *Sun's* or † *Moon's* height as I mentioned * before. Now for cleerness sake, let us suppose this *Star* to be about 45 *Degrees* high Westwardly, and then if you move your *Plane* till the said *Star*, lyes thus under a *Prick* of this height, you have (without ever moving more the *Plane*) the several following *Operations* at a time.

First, You see all the *Stars* that are then above the *Horizon* and below it; for all the painted ones within the Circle H R S T, on the second *Plane* represent the real ones then in sight, and the rest those that are below the *Horizon*. Secondly, You see what *Stars* are *Rising*, what are *Setting*, what are *Culminating*, and what are in their *Lowest Depression*. Thirdly, If you look after any particular *Star* (suppose the *Lion's Heart*) by seeing him on the *West-side* of P S (the *Meridian* of the said second *Plane*) you are sure he is not on

* p. 6.
† p. 68.
* p. 132.

ly in a *Declining* state but also (by following the *Prick* next him to the *Horizon*, according to its *Species*) that his *Azimuth* is 45 *Degrees*. *Fourthly*, You will see his *Bearing*, to be about S.W. if you follow the *Azimuthal Arch* to the *Nautical Characters* there. *Fifthly*, You see that the *Hour of the Night* is 10, by observing under what *Hour-Line* the 10th. of *April* (i.e. the day of the Month, the *Sun's* place in the *Ecliptick*) lies. *Sixthly*, By any real or imaginary *Hour-Line* that runs over the said *Star*, you find his *Right Ascension* to be near 148 *Degrees*; for thus the said *Hour-Line* cuts the *Limb*. *Seventhly*, By his being behind the *Sun* about 8 hours (as appears by the *Hour-Lines* that pass over the *Star* and the *Sun's* place) you have the *difference of their Right Ascensions*, which amounts to about 120 *Degrees*. *Eighthly*, Which is the most surprising (and not performable even by a *Celestial Globe*) you no sooner see these things in relation to this or any other particular *Star*, but at the same time, also (even without touching your *Projection*) you have them in relation to all the *Stars* in general; for when the *First Plane* is rectify'd, we have (besides the *Hour*) the *Heights*, *Azimuths*, *Bearings*, *Right Ascensions*, &c. of all the other *Stars* above the *Horizon*.

Concerning the other *Operations*, they are more restrain'd, as being peculiar to the *Star* you enquire after; for if you would know when the *Lions Heart* Sets, (which for continuation's sake we will call the *ninth Operation*) do but move your *first Plane* till the said *Star* touches the *Horizon*, and the *imaginary Hour-Line* that passeth over the *Sun's* place in the *Ecliptic*, show's you, that 'twill be then about 3 and a quarter in the morning.

107. By the *Figures* about the *Horizon*, you will see at the same time, that his *Occasive Amplitude* is near 23 *Degrees*, *Northward*, and his then *Bearing* (by the *Nautical Characters*) to be W N W, or thereabouts.

11. By the *imaginary Hour-line* that then passes over the said *Star* (viz. that of about 7 and a quarter) you have half the time of his constant aboad above the *Horizon*, and consequently know, that from his *Rising* to his *Setting* there are about 14 hours and an half.

12. By reason that the *imaginary Hour-line* of about 7 and a quarter passes over the *Star* (as we said) at his *Setting*, it follows that it's *Ascensional difference* (i.e. the difference between its

Right and Oblique Ascension) is about an *Hour* and a *quarter*, or 18 Degrees.

13. By the *Degree* of the *Ecliptic* that *Sets* with the *Star* (which is the 26 of Ω) and by the opposite *Degree* which then *Rises* (viz. the 26. of \equiv) you see that on the 8th. of *August* he *Sets* *Achronically*, and on the 2. of *February* *Cosmically*.

14. Remove the said *Plane*, till the said *Star* brushes the *Horizon* on the *East-side*, and by the precedent method (*mutatis mutandis*) you will find when he *Rises*, what his *Ortive Amplitude* is, how he then *Bears*, how long he is under the *Horizon*, when he *Rises* *Cosmically*, and when *Achronically*.

15. By placing the point of a *Pin* or *Needle*, on the *Clafs* over the *Lions Heart*, and then moving the first *Plane*, till the divided 6 a *Clock Hour-line* P E, lyes just under the said point the *Divisions* there will show its *Declination* to be about 13 Degrees and 33 Minutes. The like you may do with your *Compasses*; for if you take the *Distance* between the *Pole* and *Star*, and measure it on P E, you have what you seek for.

Many other *Operations* are performable by the *Projection*, touching the *Stars*; but since these are the most material ones, and since I have not time to treat more fully, I leave the rest to be found out by my *Reader* himself, who may easily do it, if he understands either the *Celestial Globe*, or any Instrument belonging to the *Stars*. And here he is to remember, that knowing but the *Hour* at any time, let him put the *Suns place*, or *day of the Month* under the *Hour-line*, that corresponds with it, and the *Projection* will be rectified, and consequently (having a true view of the then posture of the *Heavens*) he may operate as before. In the next place, if he knows but the *Suns* place in the *Ecliptic* of the first *Plane*, and operates with the said place as if it were a *Star*, he may find out the former *Operations* in relation to the *Sun* it self; that is to say, he may at that moment know his *Height*, *Azimuth*, *Bearing*, *Amplitude*, &c.

16. If you would know the *Stars* in the *Heavens*, you may also do it by the help of this *Projection*; for your first *Plane* being rectified, it gives you (as I said) the true posture of all the *Stars*; so that if those you seek after be near the *Horizon*, *Meridian*, or any other noted *Quarter*, those on your *Plane*

Two Memorandums.

near

near its *Horizon*, *Meridian*, or corresponding *Quarter* will resolve the Question. Or, if you take the *height* of a *Star*, and its *Azimuth* (according to any of the former Directions) then whatever *Star* on your *Plane* has the same, it will be that you seek after, and consequently you have its Name. Now knowing once a *Star*, your said first *Plane* shows you what they are that lye about it, and so by degrees you may run from one to another round the *Heavens*. Nor need you, as to the knowing of the *Stars*, be so exact (either in rectifying your *Projection*, or in having the *hour of the night*, or in taking the *Heights*, and the like) as in other *Operations*: for, by the bigness of the *Star*, by its nearness to some remarkable one, and by twenty other particular properties, you will be so regulated and confined, that you may safely conclude, when you examine your *Projection*, that the real *Star* you see, can be no other than such and such a one.

How to Describe the PROJECTION.

HAVING thus shew'd you the use of the *Pedestal* or *Projection* on, I shall fall on the way of *Describing* it, and (according to my manner all along) on the Demonstration of it also, especially since it conduces to a more easy comprehension of all *Stereographical Projections*; and if I be a little longer than ordinary, it is now no great matter, for I have ended all the *Operations* I intend at present, so that what is here further said may be omitted without inconvenience, if the Reader be disgusted at Speculation.

As for the nature of the *Projection*, tis *Optical*, representing all things in the *Heavens*, as they appear to the *Eye*, from such a Station, and not according to their true and real distances. 'Tis chiefly founded on the 20th. Proposition of the third Book of *Euclid*, which proves, that the Angle at the *Periphery* is but $\frac{1}{2}$ that at the *Center*; for from thence 'tis infer'd, that if placing our *Eye* on the superficies of the *Sphere* (v. g. at the *South Pole*) we look into its *Cavity*, the Angle made at our *Eye*, by the two *Rays* that issue from it (the one along or throu' the *Axis* to the opposite *Pole*, and the other to a determined *Point*) will be the Angle only of half the value of the *Arch*, or real distance between the two *Objects*, i. e. between the said.

said *Opposite Pole* and *Point* ; now since any *Diameter* on the *Plane* of the *Aequator* (for that, or some *Parallel Circle* to it, we now suppose to be the *Plane* of our present *Projection*) meeting with those *Rays*, will be the *Tangent* of the *Angle* they make, which being in value (as we said) but half the real distance between the said *Objects*, it must need follow, if any *Star* or *Point* in the *Heavens* be distant from this *opposite Pole*, suppose 20. Degrees, That the *Tangent* of 10 Degrees from the *Center* of the *Projection* (which represents the said *Pole*) gives its true apparrant place there, and the like is to be said of any other distance.

I shall not trouble the *Reader* with any *Scheme* to demonstrate this further, because (being fusely treated of by *Aguilinus* and others) 'tis obvious enough to all *Mathematicians*; and as for new *Beginners* (if they desire a fuller conception of it) let them but apply themselves to any man vers't in *Projections*, and in the space of ten Minutes he will shew it them more clearly and naturally, by *Strings* fix'd placed on an *Armillary Sphere*, than I can here in many hours; therefore supposing (if to such, what I have already said be not evident) that the *Heavens* may be thus projected by half *Tangents*, let us proceed to the way of doing it, that is to say, to the finding of the *Centers* and *Radius's* of all the *Circles* which conduce to the before mentioned *Operations*.

of the Concentric Circles.

As for the *Concentric Circles* of the first *Plane*, to wit, the *Aequator*, the *Tropics*, and the *Limb*, which is (as I said) *Circulus maximus semper latentium*, or some *Parallel* to it, there is no difficulty in describing them; for having drawn at right *Angles* the Lines *NS* and *EW* (representing the four *Cardinal Points*) throu' *P*, the *Center*, or projected *Pole*, if you open your *Compasses* at the *Tangens* of 45 Degrees, and place one foot on the said *P*, you must needs project the *Aequator*; because being distant from either *Pole* 90 Degrees, the *Ray* that touches it, and that which runs along the *Axis* to the opposite or *North Pole*, makes an *Angle* at your *Eye* (as we said before) of only half so much. In like manner, the *Tropic of Cancer* being 66 g. 30 m. from this *Pole*, the *Tangent* of 33 g. 15 m. gives his *Radius*, as the *Tangent* of 56. g. 45 m. does *Capricorn*, whose real distance from the said *Pole* is 113 g. 30 m. for it lies 47 Degrees beyond the former

Tropicke. And lastly, the *Tangent* of 64 g. 15 m. projects the *Limb* or uttermost *Circle*, if it be *Circulus maximus super la-*
rentium, as being yet 15 Degrees further; for the true di-
stance of that *Circle* from the said *Pole* 128 Degrees and 30
Minutes.

Now for the main matter, to wit, the great *Circles* which fall ^{The general}
^{Rule for pro-}
^{jecting the}
^{great Oblique}
^{Circles.}
obliquely on the *Plane*, take this easy general Rule for them all, *viz.* That the *r* Centers are distant from the Center of the *Pro-*
jection the *Tangent* of as many Degrees as their *Poles* are di-
stant from the *Pole* of the *Plane*, on which the *Projection* is
made (that is to say, in our present Case, from the *North-*
Pole of the *World*) and the *Secant* of the said Degrees is their
Radius.

Suppose then you were to project (v.g.) the *Ecliptic*, which ^{Of projecting}
^{the Ecliptic.}
is the only oblique *Circle* of your first *Plane*; you know that its
Northern Pole, (being in your *Meridian*) is distant from the
North Pole of the *World* 23 g. 30 m. Open therefore your
Compasses at the *Tangent* of those Degrees, and place one *Foot*
in *P*, and the other will give you in the *Line* *PN* (the *Northern*
half of the *Meridian* of your *Plane*) or in the *Line* *PS*, (the
Southern half of the said *Meridian*) the point *D*, for the re-
quir'd Center. *D* then being the Center, open but your *Com-*
passes at the *Secant* of the said Degrees, and you have the *Ra-*
dius; Nay, the Distance from *D* to *e*, or from *D* to *w*, the
East and *West Points* of the *Equator* (or points where the
Ecliptic intersects with the *Equator* on the *Sphere*) gives this
Secant; for if *PD* be the *Tangent* of 23 g. 30 m. then *De* and
Dw are (you see) the *Secants*. But before we demonstrate the
aforesaid Rule, let us make an end with the great *Oblique Cir-*
cles of the *Transparent* or second *Plane*, which are only the *Ho-*
riзон *H R S T*, and the *Azimuths* of every 10 Degrees, express
(as I said) by plain *Pricks* and *Astrisks*.

As for the *Pole* of the *Horizon*, it is (you know) the *Ze-* ^{Of projecting}
^{the Horizon.}
nith, which being distant in your *Meridian* 38 g. 30 m. South-
wards from the *North Pole* of the *World*, it must follow by
the former Rule, that the *Tangent* of 38 g. 30 m. (or *Comple-*
ment of the Elevation) from *P* (the Center of the *Projection*)
giving you (Southwards in the *Meridian* of your *Plane*) *h*, the
requir'd Center, the *Secant* of these Degrees will be the re-
quir'd *Radius*; Nay the distance from *h* to *e*, or from *h* to *w*
the

the East and West points of the Equator, (or Points where the Horizon cuts the Equinoctial Colure) gives this Secant; for if Pb be the Tangent of $38^{\circ} 30'$. be and bw are the Se-

Of projecting cants.

the primary Vertical.

The Poles of all the Azimuths, are (as every body knows) in the Horizon; now that of the Primary Vertical, being in the Meridian also, 'tis distant in the Heavens (on the North-side of your Meridian) the value of the Elevation, or $51^{\circ} 30'$. so that by the foregoing Rule (P V) the Tangent of those Degrees will, from the Center P (Northward,) give you in the Meridian of the Plane the Center of this Circle, and the Secant the Radius. Nay, the distance from V to e , or from V to w , the East and West Points of the Equator, (or points where the said Primary Vertical cuts the Equinoctial Colure) gives this Secant; for if P V be the Tangent of $51^{\circ} 30'$. Ve and Vw are the Secants. Besides, where the moving foot of your Compasses (thus extended) touches the Meridian of the Plane, there will be the Zenith in projection, and consequently distant from P (Southward,) the Tangent of $19^{\circ} 45'$. or half the Complement of the Elevation; for our Zenith lyes in the Meridian $38^{\circ} 30'$. beyond the Pole on the South-side of the Sphere or Heavens.

Of projecting the rest of the Azimuths.

As for the Centers of the other Azimuths, tho' there be no Tables calculated to shew how their respective Poles are distant from that of the Plane or Projection, and consequently the aforesaid Rule may seem useless, yet by resolving a Triangle, these Distances may be found, as also the value of the Angle, made by your Meridian (or 12 a Clock hour Circle) with the Meridian that passes thro' the proposed Degree of the Horizon, so that the Rule serves as before; for if you draw a blind Line thro' P, that makes an Angle with P N, answerable to the value of the Angle of those two Meridians in the said Triangle, the Tangent of the distance found between the Pole of the Plane and that of the propos'd Azimuth will still give you its Center from P in the said blind Line, and the Secant its Radius.

An expedite way of finding the said Centers and Radii.

But you may avoid the Resolution of a Triangle, by the usual expedite way, viz. by drawing thro' V (the Center of the Primary Vertical, found as before) the blind Line K.M. at Right Angles with P. N. (the Northern part of the Meridian of your Plane)

Plane) and then pricking on both sides of the said V (ZV being Radius) the Tangents of all the Azimuths you would express, as (for example) those of 10, 20, 30 Degrees, &c. for the said Pricks give their Centers, and the Secant of those Deg. their Radius. This Way also agrees not a little with the above mentioned Rule; for if the distance from V (the Center of the primary Vertical) to 10 (the Center of the Azimuth of 10 Degrees) be the Tangent of those Degrees, 'tis evident, that the Radius Z 10 is the Secant; and if this be the Secant, the distance from V to 10 is the Tangent. Thus then in short may be drawn (*mutatis mutandis*) all other great oblique Circles in any Steriographical Projection, when their Poles lye in one and the same Circle; and now since the aforesaid Rule agrees even with this usual way of describing these Circles, I will here Demonstrate it, having done with the great Circles on both our Planes; for as to the Hour Circles, they are all seen in Cylindrical, (that is to say, they lye directly under your Eye, and consequently are in projection straight Lines, and distant (as on the Sphere) 15 Deg. asunder, I say, since the Rule agrees not a little with this way, and that I have done with the great Circles both Planes, I will now demonstrate it by the two Lemmas that follow.

The Demonstration.

I. The Secant of any Arch is equal to the Tangent of the Lemma 1.

That is to say, CE the Secant (for example sake) of 60 Degrees (in Scheme 5) is equal to EB (the Tangent of 60) and to BA the Tangent of 15, or half the Complement of 60: For the Angle ECA being equal by Hyp. to the Angle ACH, becomes equal to * the Angle EAC, therefore EA is equal to † EC, and consequently EB plus BA is equal to EC. QED.



* Encl. 27. 2.
† 6. 1.

II. The Tangent of any Arch greater than 45 Degrees is equal to the Tangent and Secant of double its Excess above 45 Degrees; that is to say, AB Tangent (for example) of 46 Deg. (in Sch. 6th) is equal to CD Secant of 2 Degrees plus DB Tangent of the said Degrees; for the Angle DCA being by Hyp. † equal to the Angle ACH becomes equal to the



Lemma 2.

† Encl. 27. 1.

*6. I.

The Ecliptic
truly proje-
cted.

Angle DAC, therefore CD is equal to * AD, and consequently AD plus DB is equal to CD plus DB.

These two Lemmas being premis'd, let us consider the Projection (for example sake) of the Ecliptic, and see how it agrees with our said Rule, to wit, That the Centers of all the projected great oblique Circles are distant from the Center of the Projection, the Tangent of as many Degrees as their Poles are distant from the Pole of the Plane on which the Projection is made and that the Secant of those Degrees gives their Radius's. The Ecliptic is to touch both Tropics on the Solstitial Colure or Meridian of the Plane, because it touches that Colure thus in the Heavens, and on the Sphere; so that by Construction P S (the distance in Projection between the Center of the Plane and the Point where the Ecliptic touches the Tropic of Cancer) is the Tangent 33. 15'. or half 66. 30', (its real distance on the Sphere from the North Pole) and on the other side P W (the distance in Projection between the Center and the Point where the Ecliptic touches Capricorn) is the Tangent of 56. 45. or half 113. 30'. its real distance as before. Now D by Construction being distant (on the Meridian or Diameter of the Plane) from the Center P the Tangent of 23 d. 30 m. (or real distance between the Pole of the Plane of the Projection and that of the Ecliptic) must needs be, according to our Rule, the Center of this Circle in Projection, and the Secant of those Degrees its Radius, if we prove the said D to be the middle of the Line S W (or Diameter of the Ecliptic) and D S and D W to be Secants of 23 d. 30 m.

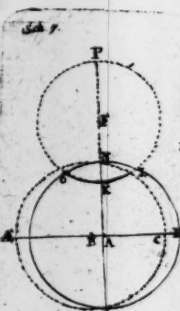
'Tis manifest that D S is Secant of 23 d. 30 m. because 'tis equal (by Lem. 1.) to PD, Tangent of 23 d. 30 m. plus P 69 Tangent of 33 d. 15 m.

Again D W is Secant of 22 d. 30 m. because P W (Tangent of 56 d. 45 m.) is equal by Lemma the second to the Tangent and Secant of 23 d. 30 m. Now P D being Tangent of those Degrees, D W must be Secant; therefore D S and D W being equal, D is the middle of the Line S, W, and consequently P D (the Tangent of 23 d. 30 m. from the Center of your Plane) gives in its Meridian the Center of the Ecliptic, and the Secant of those Degrees the Radius, Q. E. D. and in this manner the way of projecting the other great oblique Circles is to be demonstrated.

Nor

Nor do's this Rule solely serve for the Description of the great Oblique Circles on the present Planes, but for all that are expressed on Stofflers Astrolabe, or Mr. Oughtreds Horizontal; Nay it shews not only how to draw the Meridians in Gemma Frisius his Projection, but, by the bare conversion of the Terms, the Parallels themselves, tho little Circles.

For first as to the Meridians, whose Poles, (as every body knows) lye all in the Equator, suppose you would describe the 10th. from the Limb or grand Meridian, which is to be the Solstitial Colure, since, in this Projection, your Eye lies in the East or West points of the Equator, to wit in the Pole of the said Colure; I say, suppose you were to describe the 10th. from the Limb, it follows by our Rule, because their Poles are 10 Degrees asunder on the Sphere and in the Heavens, that the Tangent of those Degrees gives from A (the Center of the Projection in Sch. 7th.) the requir'd Center B, and the Secant the Radius; For this Circle on the Sphere cutting the Equator at the 80th. Deg. from the Pole of your Plane, (or point opposite to your Eye) its extremity C must in Projection be distant from A the Tangent of 40 Deg. only; Now since BC (to wit BA plus AC the Tangents of 10 and 40 Deg.) is equal by Lemma the first) to the Secant of 10 Degrees, and since BN. and BS (or distance from B to the two Poles of the World) are visibly the Secants of those Degrees, it necessarily follows, that the Meridian to be describ'd (which pass we know throu' the said three points C. N. and S.) can have no other Center but B, nor Radius but the said Secant. Besides if we make this Arch an entire Circle (by the prick'd Arch NÆS) then AB the Tangent of 10 Degrees plus BÆ = BC (the Secant of 10) is equal (by Lemma the 2d. to the Tangent of 50 Degrees, but the other part of the said Meridian lyes (we know on the Sphere) 100 Degrees from the forementioned Pole of the Plane, and in projection the Tangent of 50 from the Center A; ergo B is the true Center of the requir'd Meridian, and the Secant of 10 Degrees the Radius.



2. For the Parallels or Circles of Latitude, the same Rule (the Terms as I said being converted) finds both their Centers and Radii's; for if you would project (suppose) the 80th. Parallel from the Equator, that is to say, the 10th. from the Pole of the World, 'tis but saying, That the Secant of

10 Degrees from the Center of the Plane gives you the Center of the Parallel requir'd, and the Tangent of the same Degrees the Radius. To prove this, let AF (in Sch. 7.) be by Construction the Secant of 10 Degrees, and opening your Compasses at the Tangent of those Degrees place one foot on the said F, and describe the Circle KLP O; Now because AF the Secant of 10 Degrees is equal (by Lemma the 1st.) to the Tangent of 10 and Tangent of 40 Degrees, therefore AK is the Tangent of 40 Degrees. Again because AF (Secant of 10) plus FP = FK (Tangent of 10 Degrees) is (by Lemma the 2d) equal to the Tangent of 50, ergo AP is Tangent of 50; but the Parallel requir'd is a Circle which on one side cuts (in the Sphere) the Equinoctial Colure 80 Degrees from the Pole of your Plane (or point opposite to your Eye) and on the other side at 100, or supplement of the said 80 Degrees, therefore seeing K and P the two extreme points of the projected Circle OPLK are distant from the Center A on the produc'd Axis (or intersection of the Equinoctial Colure with the Plane) the Tangents of 40 and 50 Degrees (to wit, the Tangents of half the real value of these Arches) it must follow that the said OPLK truly represents the requir'd Parallel, and consequently that the Arch OKL is that part of it, which is farthest from your Eye, to wit, so much of the whole Circle as falls on the Plane. Thus much then for these Parallels, since all are to be describ'd after the same manner, and now having mention'd little Circles, 'tis fit the Reader should know how the Circles of Altitude are to be describ'd on the second Plane of the Pedestal or Projection which are little Circles also.

How to describe the Circles of Altitude on the 2. Plane.

The way is easy for if you would have the Almucantar, (suppose) of 10 Degrees (viz. *abcd* in Scheme 4th) you must proceed thus. Because the Horizon in projection (as we shew'd you before) is distant from the Center, (on the North side of the Meridian) the Tangent of 25, 45m. or half the Elevation, to wit from P to H, and (on the South side) from P to S, the Tangent of 64. 15, or half 128. 30'. the supplement of the said Elevation, therefore the Almucantar of 10 Degrees (being on the Sphere 10 Degrees nearer the Pole than the Horizon,) will in projection be nearer the Center 5 Degrees. So that the Tangent of 20, 45^l from the Center P giving (a) its extremity on the North side of the Meridian, and the Tangent of 59. 15. giving (c) its extremity on the South side, it follows that (e) half the distance between the said (a) and c becomes the Center to describe it by; For since all the Circles of the Sphere

are still *Circles* in projection (except those that are seen in *Culiro* (as we said) if you have the *Diameter* (or *streight Line* that joyns the *extreme points* of any of them) half of it must needs give you the *Center*; and in this manner then are the other *Circles of Altitude*, to be describ'd. But here take notice that whereas in *Sch. 2.* (representing the second or *transparent Plane*) the *Azimuths* and *Almucantars* are found (as I shew'd you) by the consideration of the *Pricks* or *Asterisks* there exp^{re}it: Now, that the *Reader* may know how to Place them, the very *Circles* and *Arches* are describ'd on it, *Sch. 4.* as it represents for the said *Pricks* and *Asterisks* are ever to be in their inter-
sections. And by way the *Instrument maker* may (if he pleases) make use of *Pricks*, and no *Asterisks* on the real *Trans-
parent Plane* of the *Pedestal*; for they will upon second thoughts perform better the *Operation*.

The Conclusion.

HAVING thus finish'd all the *Operations* that at present occur; I shall now end with what I promis'd in the * Beginning, to wit, with showing the *Reader* the particular *Advantages* of this *Globe*, which are of four kinds; For, First it does several *Operations* not performable by the *Ordinary Globes*. 2ly. It does even the *Operations* (which the other perform) much easier and quicker. 3ly. It performs many at a view, which are to be done by the other (for the most part) successively. Lastly, It has several by-advantages and conveniences belonging to it by it's *Make* independent of the *Operations*.

As to the *Operations* not performable by any other *Globe*, they are :

1. The placing of it self * *Level*, or *Horizontal*. * pag. 4.
2. The † *Composing* of it self to the *Position* of the *Heavens*. † p 8. & 15.
3. The showing of the * *Hour*, even severall wayes : and th's * pag. 13.
not only at *Home* but at the same time also in all † *Places* † p. 31.
of the *World*. * pag. 36.
4. The knowing how much any place wants of *Day*, if it be *Night* there; or of *Night* if *Day* there; and consequently the † *Babilonish* and *Italian Hour* without any *Compu-
tation*. † pag. 32.
5. The showing the * *Judaical Hour*, without any *Computa-
tion*. * p. 40.

- * p. 35. 6. *The showing the Sun's true Place in the Heavens every Moment, and consequently in what Countrey he is then Vertical.*
- * p. 5. 7. *The Sun's height at any time of the Day both at * home,*
 ‡ p. 37. *and in all other ‡ Places, where the Globe show's 'tis Day, as also his Depression where it show's 'tis Night.*
- * p. 10. 8. *The Sun's * Azimuth and ‡ Bearing.*
 ‡ p. 11. 9. *The Antient * Geography as well as Modern.*
 * p. 21. 10. *The Hour by the ‡ Moon; with several other Operations concerning her.*
 ‡ p. 51. 11. *The * proportion of Perpendiculars to their shades, with Corollaries in relation to Alimetry, and showing the Hour by your stick.*
- * p. 65. 12. *The performing of all the accidental * Requisites to Dialling, as how to draw Meridian Lines, and Lines Parallel to the Horizon, how to find the Declension of all Planes, as also their Reclination, Inclination, &c.*
- * p. 70.

A Memorandum.

But here the Reader must remember, that when I say none of the forementioned Operations are performable by other Globes, I mean not this alwayes in a strict sence; for if (suppose) we have the *Hour of the Day* given, we may then (as every body knows) soon find by it the *Sun's height*, or if (suppose) we have his *Azimuth*, we have the *Hour*; I say, I mean not this alwayes in a strict Sence, but call all these Operations not performable by other Globes, since they at first require (for the Operations they do) something as hard to be found as what we seek after; whereas by exposing only of this *Globe* to the *Sun*, and having but the day of the Month, most of the Premises present themselves to us at all times with as much facility as the very *Hour* it self by an *Horizontal Dial*.

Besides, the Reader must know, if a *Brazen graduated Semi-Circle* were hung on the *Poles* here, with an erected moveable *Pin*, or *Cursor* on it, there would be no need of the *Holes* (I* formerly mention'd) in each *Parallel* of the *Globe*, for the true Composing of it; Nay this *Semi-Circle* (omitting several other things) will also give the *hour*, by being still directly over it, as often as 'tis moved into the *Plane* of the *Sun*; but seeing I pretend to show all the Operations here treated of, even on a naked and free *Globe*, by the sole help of a little *String* or *Tread*, I hint only the said *Semi-Circle*, that the Reader may
 use

* p. 8.

use it, if he shall judge it any time fit for his business.

In the second place, as to the Operations common to all 2^d kind. Globes, but more easily perform'd by this, take some few Examples that follow.

1. If you would find (suppose) the Aurora by the Common Globes, you must (after knowing the Day of the Month, or Sun's place in the Ecliptic) bring it to the Meridian; then you must put the Index Horarius on 12, and so move the said Sun's place to the East side of the Horizon. Afterwards you must find the opposite Point to the Sun's place, and fixing your Quadrant of Altitude in the Zenith; you must mount the said opposite Point till it meet with the 18th Degree, and then the Index gives you what you seek for, whereas by This Globe you have nothing to do but to * depress your Bead 18 Degrees below the Horizon, and to move the String on the Zenith till the said Bead touches the Parallel of the Day on the East side of the Globe; for then it lyes on the requir'd Hour. * p. 13.

2. If you would but know when the Sun rises by the other Globes; you must (after finding of the Sun's place) lay your Index on 12 and when you have brought the said Place to the East side of the Horizon, the Index will shew the Hour: Whereas now the * Intersection of the Parallel of the day with the Horizon performs the Operation without more a-doe.

3. If you would know the Ascensional Difference by the other Globes, you must first find the Right Ascension, then you must find the Oblique, and lastly you must substract the greater from the less; whereas here the * distance on the Parallel of the day (which the Hour-Circles measure) between the 6 a clock hour circle and the intersection of the said Parallel with the Horizon gives at a view the requir'd Ascensional Difference in time, and consequently in Degrees. I shall not trouble my Reader with more Instances at present, leaving the rest to his own Observation, and he will still find (at least generally speaking.) That the Operations (as I said) common to both Globes are more easily and readily perform'd by this than by any other. * p. 2.

As to the Advantages of the third kind, to wit, The performing several Operations at one view, which are perform'd successively by other Globes, there are at least 15 that present themselves to you (the Globe being compos'd) as soon as ever you have made the Shade of the String (hanging on the Zenith) to pass 3 kind.

pass throu' the *Nadir*; for then you have before your Eyes.

- * p. 14. 1. The Hour of the Day; by considering the shade of the * illuminated Pole.
- 2. The Day of the Month; by considering on what Diurnal Parallel the Shade of the String marks the same Hour with that shewn by the shade of the said illuminated Pole.
- * p. 15. 3. The Place where the Sun is Vertical; by considering the Sun's * place in his Parallel, and consequently the Country under it.
- * p. 25. 4. The Sun's Sign or Place in the Ecliptic; by considering (according to the Increment or Decrement of the Days) throu' what part of the * Ecliptic the Parallel of the Day passes.
- * p. 13. 5. The Sun's Declination; by considering throu' what * Degree of the Equinoctial Colure, the Parallel of the Day passes.
- * p. 11. 6. The Sun's Azimuth and Bearing; by considering what * Degree of the Horizon and what Nautical Character, are cut by the shade of the String hanging from the Zenith.
- * p. 10. & 12 7. The time of the Sun's Rising and Setting, by considering on what * hour circle the Parallel of the Day and Horizon intersect on the East and West sides of the Globe.
- * p. 16. 8. The length of the Day and Night; by considering how many Hour-Circles cross that part of the Diurnal Parallel which is above the Horizon; for they show the length of the Day, as the Hour-Circles, that cross the part under the Horizon, do the length of the Night.
- * p. 17. 9. The Sun's Ascensional Difference; by considering the * Hour-Circles on the Parallel of the Day between the 6 a clock Hour-Circle, and the intersection of the said Parallel with the Horizon.
- * p. 19. 10. The Sun's Amplitude; by considering how many * Degrees in the Horizon the Sun rises from the true East Point, or sets from true West.
- * p. 17. 11. Where 'tis Day or Night over all the World; by considering the * illuminated and obscur'd parts of the Globe; for the one show's ever where 'tis Day, and the other where 'tis Night.
- * p. 33. 12. Where they enjoy nothing but Day, and where nothing but Night: by considering the * Illumination and Obscuration about

about the Poles: for a Circle describ'd about the illuminated Pole, to the nearest shade of Extuberancy, shows, that all the Inhabitants within that Circle have nothing but Day, and that all they that dwell within the like Circle about the obscur'd Pole, have nothing but Night.

13. Where the Sun is Rising and Setting all the World over; by considering the *preceeding and following shade of Extuberancy; for the first, show's the people to whom the Sun then is Rising, and the other to whom the Sun is then Setting. * p. 34.

14. How many hours any place wants of day or night; by considering first a Parallel to run over the Place propos'd, and then by reckoning the number of * Hours between the said place, and the *preceeding, and following shade of Extuberancy; the one bringing with it Day and the other Night. * p. 36.

15. What a clock 'tis all the World over; by considering (according to the little Polar Figures) the * Hour-Circle that * passes over any place, and adding to the time thus found (if it be in the afternoon) as many hours as are past since Midday with you, or subtracting (if it be in the Morning) as many Hours as you want of Midday. * p. 37.

Now for the last kind of Conveniences, which this Globe Challenges, to it self, to wit, Those independent of the Operations, 4th kind. they are 4.

1. For, First It takes up little or no room wheresoever it stands, the bottom of the Pedestal not being ordinarily much bigger, than the foot of a large hour-glass, whereas other Globes are cumberfom, and embarras any Table or Place on which you set them.

2. It is wholly expos'd to our Eye as well below as above the Horizon; whereas the Frame, Meridian, and the other Appendices of common Globes, always hide more than half of them.

3. It is as cheap as a single ordinary Globe, and yet performs the Operations of the Terrestrial and Celestial ones.

4. It never declines from its Position; whereas other Globes by moving on their Poles encline presently more or less to this or that side of the Meridian and Horizon, so, that (besides their usual grating) all the Operations become sensibly false.

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